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LOS ALAMOS SCIENTIFIC LABORATORY

of

THE UNIVERSITY OF CALIFORNIA

Report written:
July 1946

LA-1161

This document consists of 158 pages.

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NUCLEAR WEAPONS

ENGINEERING AND DELIVERY

Volume 23

Los Alamos Technical Series (U)

Compiled by:

Norman Ramsey
Raymond L. Brin

CIRCULATION LIMITED

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Seth Neddermeyer ?

sively tested at Dahlgren beginning on December 3, 1943.

OK

In September, 1943, the fast-implosion model was proposed by John Von Neumann as an alternative to the slow implosion. As it became clear that this model was a promising one, preliminary planning for converting it into a bomb was begun. A preliminary estimate of 59 inches diameter and 9000-pound weight was made by Von Neumann and Ramsey, and on this basis the Bureau of Standards bomb group was asked to design suitable fairing and stabilizing fins for such a bomb.

In the Fall of 1943 it became apparent that plans for full-scale tests should be started. In view of the critical shortage of B-29's it was first proposed that a British Lancaster be used for the test work, even though a B-29 would almost certainly be used as the combat ship. The Air Force, however, wisely recommended that a B-29 be used for the test work as well, both to avoid non-standard maintenance and to accumulate experience in B-29 operations with such a bomb. In order that the aircraft modifications could begin, Parsons and Ramsey selected two external shapes and weights as representative of the current plans at Site Y (Project Y). One of these was 204 inches long with a maximum diameter of 23 inches and was a model for the current gun assembly. The other was 111 inches long and 59 inches in diameter, corresponding to a fast-implosion assembly. For security reasons, these were called by the Air Force representatives the "Thin Man" and "Fat Man", respectively; the Air Force officers tried to make their phone conversations sound as though they were modifying a plane to carry Roosevelt (the Thin Man) and Churchill (the Fat Man). Models to these dimensions were ordered from Detroit. Modification of the first B-29 officially began November 29, 1943. Colonel R. C. Wilson was Army Air Forces Project Officer for all aspects of the program, Colonel D. L. Putt at Wright Field was in charge of the division under whose supervision the modification was done, and Captain R. L. Roark was Project Officer in charge of modification.

Tests with the modified aircraft and full-scale dummy bombs were begun at Muroc, California on March 3, 1944. Brode's fuzing group, Bainbridge's instrumentation group, and the delivery group participated in these tests. Coordination of the activities of the different groups in these and subsequent field tests was a responsibility of Ramsey's delivery group. The purpose of the tests was to check the suitability of the fuzing equipment, the stability and ballistic characteristics of the bombs, the facilities then available for field work, and the suitability of the aircraft to carry and drop the bombs. After four weeks of delay, due to torrential rain on the Mojave Desert and aircraft troubles, a series of tests was completed. The negative results of most of these tests thoroughly justified preliminary tests at such an early date. The fuzes proved to be unreliable and, on the basis of these results, an investigation of the possibility of adapting an AFS-13 fighter tail-warning radar to this use was begun. The Thin Man proved to be very stable in its flight, but the Fat Man -- with a tail that the Bureau of Standards bomb group thought would be extremely stable --, proved to wobble badly with its axis departing 20° from the line of flight. Although the B-29 release mechanism worked satisfactorily for the Fat Man, it failed completely for the Thin Man. Four of the units were bad hang-ups with delays up to 10 seconds, and the final drop was 20 minutes premature while the plane was still climbing to altitude. The bomb in this case fell onto the bomb-bay door which was badly damaged, when the door had to be opened to jettison the bomb. With this accident, the first Muroc tests were brought to an abrupt and spectacular end.

Between the end of the first tests and June 1944, all groups worked to correct the faults demonstrated in the first tests. [redacted]

DOE b(3)

Detailed designing of this shorter model was begun during this period under the supervision of E. M. McMillan and F. A. Birch. Because of the contrast in dimensions with the Thin Man, this model finally acquired the appropriate name of Little Boy. At the same time the detailed designing of the 1222 form of Fat Man assembly was begun. [redacted]

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Tests at Muroc were resumed in June, 1944. These tests confirmed previous results in that the first form of fuze being developed

[redacted]

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at Michigan was not satisfactory. The first two APS-13's became available to Project Y during the test, and two haywire drop tests (genuine baling wire was actually used) were made with a field adaptation of this equipment to fuzing. The earlier of these provided the first completely satisfactory fuzing test; and, although the second failed, it was probable that the failure was in some of the hastily prepared auxiliary equipment. The Fat Man, its tail assembly modified from the original circular shroud to a square shroud 59 inches on a side, still proved unstable. As a desperate last resort, Captain David Semple, Project Bombardier, suggested a drop be made with internal 45° baffle plates welded into the inside of the shroud as a field modification. To everyone's surprise, this modification was successful, the bomb being completely stable in its flight and the ballistic coefficient being improved rather than decreased as anticipated. No release failures were experienced in the tests.

Adm Ashwor says this was Parso suggestion. 7/11/78

From the end of these tests until October, 1944 when similar field tests were resumed, a strenuous program of design and procurement was under way at Site Y to obtain units that could be used as components of an actual atomic bomb rather than units that were merely ballistic models. Three basically different models were on hand at this time. One was the Little Boy model of the U^{235} gun assembly, another was the 1222 Fat Man model of implosion assembly, and the third was a model which evolved into the finally adopted 1561 Fat Man implosion assembly. The latter arose from a redesign for the purposes of simplifying the assembly problem (the assembly of 1222 required the insertion of more than 1500 bolts) and of improving

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[redacted]

the flight characteristics (by using an ellipsoidal shape for the outer armor). The model finally adopted comprised an inner spherical shell, consisting of two polar caps and a segmented central zone which could be bolted together; this was surrounded by an ellipsoidal armor to which a stabilizing tail, including the necessary drag plates, was attached. The auxiliary fuzing and electrical detonating equipment were mounted in the space between the inner sphere and the outer ellipsoid.

In August of 1943, Colonel R. C. Wilson and Colonel M. C. Demler visited Site Y and recommended that the Air Forces begin immediate training of a combat unit for the delivery of the atomic bomb. It was agreed, therefore, that Site Y (by September 1, 1944) should freeze the external shapes of the three models and other requirements affecting aircraft, so that modification of a production lot of fifteen B-29's could be started. These aircraft were modified at the Martin-Nebraska Plant at Omaha, and the first aircraft became available in October, 1944. Sheldon H. Dike and Milo M. Bolstad were the Project Y representatives during these and subsequent modifications. The special modifications for carrying and releasing the bomb were designed to incorporate the British F and G release mechanism currently used for the British 12,000-pound bomb. This mechanism required only a single lug on the bomb. At this time, Wendover Army Air Base, Wendover, Utah was designated as the center at which training of the new Atomic Bomb Group would be undertaken and at which future field tests would be held. The Second Air Force under General Uzel G. Ent, and later under General Robert B. Williams, was designated as the parent organization of this group. Colonel Paul W. Tibbets with an X-unit), and greatly complicated the scheduling of tests since there was at no time a backlog of X-units. The tightness of schedule resulting from this is best illustrated by the fact that it was not until the end of July that sufficient X-units had been tested to confirm their safety with HE; the first HE-filled Fat Man with an X-unit was tested at Wendover on August 4, 1945; the next HE-filled Fat Man with an X-unit was tested at Tinian on August 8, 1945; and the first complete Fat Man with active material was dropped on Nagasaki on August 9, 1945. Despite these difficulties, however, a total of 155 test units was dropped at Wendover or the Salton Sea between October and the middle of August 1945. Much information gathered in these tests were incorporated into the design of the bombs.

Planning for overseas operations was one of the principal activities of Project A during this period. Initial planning and procurement of some kits of tools, etc., began in December, with these activities continuing at an accelerated rate through July. In February of 1945 Commander F. L. Ashworth was sent to Tinian to make a preliminary survey of the location and to select a site for our activities. By March, the construction needs for the Tinian Base were frozen as follows: four air-conditioned 20' x 48' steel rib buildings of the type normally used in the Navy for bomb-sight repair (two for the fuzing team, one for the electrical-detonator team, and one for joint use by the pit team and observation team), three air-conditioned 20' x 70' assembly buildings for which the materials were accumulated at Inyokern, five 40' x 100' steel arch rib warehouse buildings, one building of the same type house as a modification shop, three 10' x 10' x 5' magazines, seven 20' x 50' x 10' magazines, and two special loading pits equipped with hydraulic lifts for loading bombs into the aircraft. A third such pit was constructed at Iwo Jima for possible emergency use. Materials for equipping the buildings and for handling heavy equipment in assembly, tools, scientific instruments, and general supplies, were all included in special kits prepared by the different groups. A kit for a central stock room was also started, but the materials were not shipped by August 4, 1945 (at which time further shipments to Tinian were stopped by the end of the war). Construction of the Tinian base began in April under the supervision of Colonel E. E. Kirkpatrick.

Beginning in May, so-called "batches" of kit materials and of components for test and combat units were transported by ship to Tinian. A total of five batch shipments were made. In addition, a number of air shipments in five C-54 aircraft attached to the 509th Group was made for critically needed items. The availability of these C-54's for emergency shipments contributed greatly to the ability of Project A to meet its schedules in combat use of the atomic bomb.

CHAPTER 2

DESIGN AND ASSEMBLY OF PIT FOR MODEL 1561 FAT MAN *

M. G. Holloway and R. E. Schreiber

2.1 THE PIT

This chapter describes the design and assembly of the Pit, the responsibility for which was primarily assigned to the G-Engineer Group.

DOE b(3)

The general arrangement and appearance of these parts is shown in Figure 1.

DOE b(3)

* This Chapter was previously issued as LA 619(1946)

The lens charge was lowered into position in the same manner as the inner charge, and produced no observable change in the counting rate.

The mock-fission source was then removed. [redacted] With the paraffin sheath removed, the counting rate was so low that no good measure could be made of it in the time available. The time was then 1745 hours.

DOE b(3)

The Explosives Group removed the modified polar cap and replaced it with the standard polar cap. After the cap was bolted down, the piano wire was removed from the hypodermic (which now protruded through a small hole in the polar cap). At 1807 hours, a manganese alloy wire was inserted into the hypodermic. The work of the G-Engineers Group was now almost finished.

Five manganese activations were made before the shot. The last any member of the G-Engineers Group saw of the gadget was at 1626, 15 July 1945, when the final activated manganese wire was removed from the gadget on top of the tower.

On 14 July, the G-Engineer Group packed their equipment at McDonald's ranch and loaded it into a truck for removal to the base camp.

CHAPTER 3

MECHANICAL DESIGN OF MODEL 1561 FAT MAN

A. H. Machen

3.1 INTRODUCTION

This Chapter is concerned with the design of the case, the equipment supports, the lugs, and other external parts of the 1561 model Fat Man. The design of the pit containing the active material for this bomb is discussed in the preceding chapter of this Volume; and the design of the high-explosive components is discussed in Volume XI of the Los Alamos Technical Series.

Figure 1 is an artist's drawing of an early form of the Fat Man model. From that Figure, it can be seen that the model consisted essentially of a large sphere containing the explosives and active material, mounting provisions for auxiliary electronic equipment, an outer armor steel cover, lift lug, and a stabilizing tail assembly. This Chapter will discuss these components of the assembly. A collection of the mechanical drawings of the final form of the 1561 model Fat Man that was used in combat may be found in LA-392.

3.2 DESIGN OF THE SPHERE

Design of the sphere was started with the following specifications:

(1)

(2) A size within the limits of the bomb bay of a B-29

airplane with a fall angle of five degrees;

(3) Provision of detonation holes for more than one detonation pattern.

The first model was the 1222 (Figure 2). Its spherical case was divided by great circles into twelve equal pentagons bolted together by edge flanges; machining these pentagons to a close enough tolerance to permit bolting-up into a complete sphere turned out to be highly impractical.

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This model was further complicated by a steel case consisting of twenty triangles secured to the sphere by some eleven hundred bolts screwed into holes radially drilled and tapped into the flanges of the pentagon. A steel lift-lug pad, designed to distribute the lug load out into the spherical case, was provided and secured to the sphere at the apex of the top five pentagons.

DOE b(3)

A complete departure from the 1222 pentagon structure was made in the 1291 model (Figure 3) using the same polar cap and belt-band design that was used in the final model. The 1291 model consisted of three spherical zone segments bolted together by 18 bolts screwing into tapped flanges to form a belt section of the sphere. The sphere was completed by two polar caps bolted to the tapped flanges of the belt section.

DOE b(3)

staked into holes drilled in the case for fast, easy mounting of the 110 wire harness clips necessary to hold the coaxial detonator cables (Figure 5).

3.3 MOUNTING OF ELECTRONIC INSTRUMENTS

The mounting of the instruments in the early stages of 1222 design presented few problems. For example, the firing circuit was a small box weighing a few pounds, whereas the final unit was a cast dural tub, weighing about 300 pounds. All of the instruments of this first unit were supported on a single tubular mount attached to the aft side of the sphere (Figure 6), and it was not until after the start of the 1560 model that any of the instruments were placed forward of the sphere. By this time, all the space within the ellipsoidal covers, fore and aft, was occupied by firing and fuzing circuits. The tubular mounting brackets were used fore and aft on the 1222, but discarded on the 1560. A dural cone was designed that would tie into the polar cap bolts, supporting the 300-pound firing circuit box in front and a panel of fuzing instruments aft without danger of vibration. Fast, accurate assembly was kept in mind throughout this design; although the bomb could be a hand-tailored job in most respects, speed was very important in the assembly of the hot model.

A mounting plate was provided for the firing-circuit charging equipment. This plate, mounted in the nose of the front ellipsoid, was accessible through the removable nose plate, and provided a means of battery installation after assembly of the bomb (Figure 7). All instrument plates required constant attention, since changes and rearranging of parts made new layouts necessary to check clearances

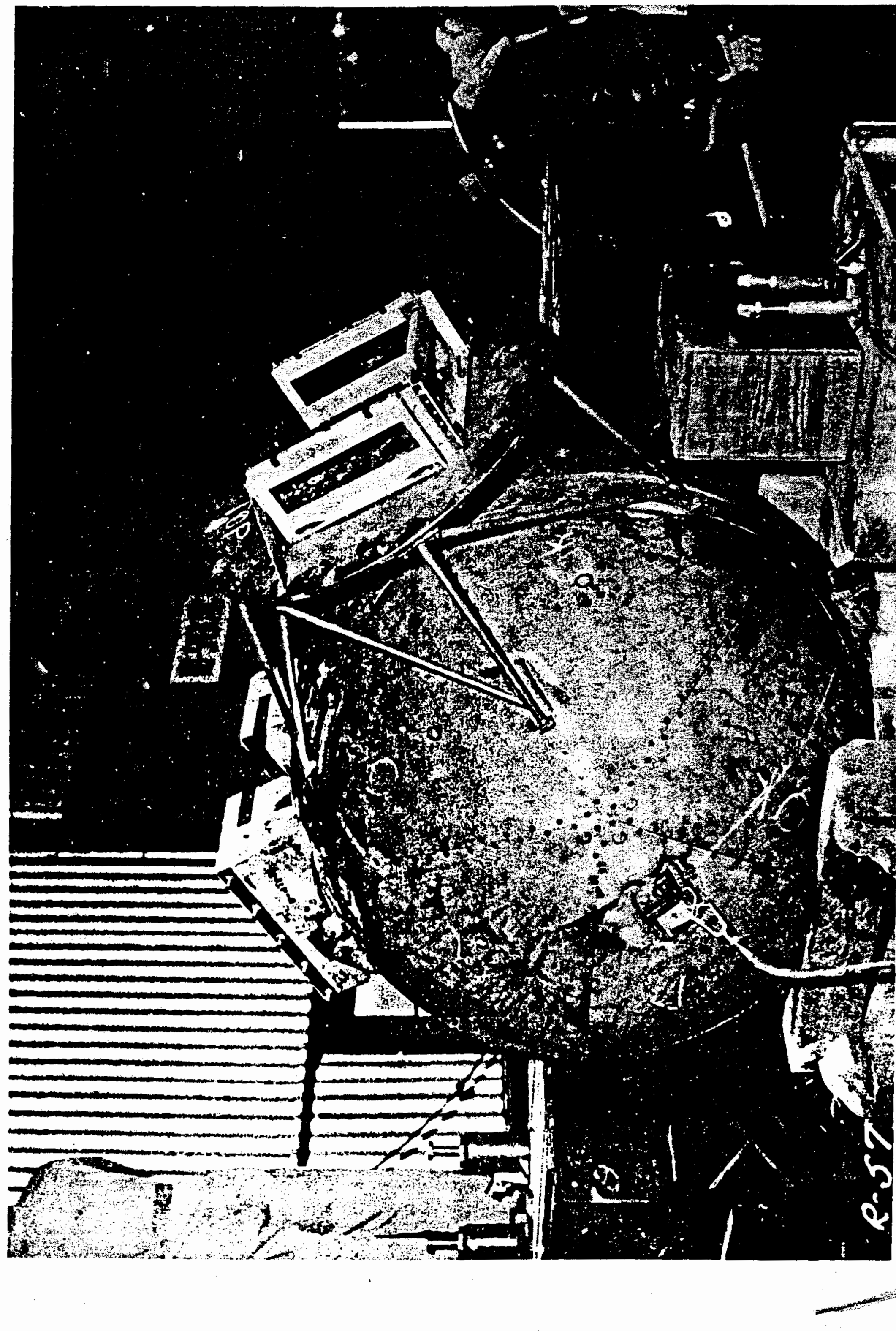

Figure 6

CHAPTER 4

ASSEMBLY OF THE 1561 FAT MAN

V. A. Miller

4.1 INTRODUCTION

This Chapter is devoted to a history of the development of buildings, equipment and procedures for the assembly of the 1561 Fat Man bomb. Since that bomb was an entirely new type, no standard equipment or operation procedures were available; consequently, buildings and equipment had to be developed as a result of problems and experience encountered in the early stages of the bomb design. This Chapter will discuss the design of assembly buildings, the supply problems for Wendover and the overseas destination, assembly handling equipment, and the transportation of the bomb.

4.2 BUILDING DEVELOPMENT

The original assembly building at Wendover was a Butler building, 40 by 80 feet. It was equipped with two 1-ton chain hoists and two 6-ton chain hoists. The building had an addition approximately 15 by 15 feet with a 6-ton traveling hoist on one end that was closed off from the other portion of the building and used as a paint shop and delivery room of completed test models. This building was not air-conditioned and since it was also used as a modification building, it was very inadequate for the construction of any but concrete bomb models. The building was used until April of 1945 when a building was completed for assembling HE models.

CHAPTER 5

ATOMIC-BOMB PROJECT AIRCRAFT

S. H. Dike

5.1 AIRCRAFT USED FOR ATOMIC-BOMB DELIVERY

The first bomb dropped in connection with this project was released from a TBF at Dahlgren Naval Proving Ground, Virginia, on August 13, 1943. This test, witnessed by N. F. Ramsey, was for ballistic data only. The first drop made in connection with fuze research was made from an SNB-1 (AT-11) at Dahlgren on December 3, 1943.

In the early days, several types of aircraft were considered for carrying the atomic bomb. The shape of the bomb then was very different from either of the two final types. The British Lancaster and our own B-29 were the two planes most seriously considered for the final delivery job. In the early summer of 1943, the B-29 was a new airplane; its performance was still more or less unknown and production rates were not definitely planned.

It was decided in November, 1943, to modify a B-29 at Wright Field for project use. Accordingly B-29 No. 42-6259 was procured. This was the 69th Wichita production airplane.

At that time, there were two distinct types of bombs which Project Y wished to drop. These were known as the "Fat Man" (Figure 1) and the "Thin Man" (Figure 2). The "Thin Man" became obsolete later in the program and evolved into the "Little Boy".

The first "Fat Man" shape was changed considerably, but overall external dimensions remained about the same.

During December, 1943 and January, 1944, the necessary modifications were made at Wright Field under the supervision of Major (then Captain) R. L. Roark. A large part of the mechanical-engineering design was done by Mr. Charles Speer, a civilian Engineer at Wright Field. The crew assigned to the B-29 included Major C. S. Shields, (pilot) and Captain Dave Semple, (Bombardier). Captain Semple followed the modifications concerning the release and bombing circuits.

The modifications of the first B-29 included: changes in the bomb doors; installation of a carrier frame, sway-bracing; and release for the Fat Man bomb model; installation of release and sway-bracing for the Thin Man bomb model; and installation of the special wiring circuits required by the Fuzing Group. Several Eyemo Cameras were installed in the bomb bay for photographing the release and initial bomb flights. The release used was a modification of a standard glider tow release; two of these, tied together mechanically, were used. The bombs were fitted with two suspension lugs.

The modifications were completed in early February, 1944, and the B-29 was flown to Muroc Army Air Base, California, to undergo the first series of tests, arriving there February 20, 1944. Two test drops were made on February 28 with standard inert bombs for ground crew camera practice. The first drop of the Thin Man model bomb from a B-29 was made on March 3, 1944.

Failures in the bomb-release system occurred during the first series of tests. It was erroneously believed that, once the toggle of

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the glider tow release was pulled past dead center, the weight of the bomb would open the release. This was later proven not to be the case. In order to effect proper release, sufficient force must be applied to actually pull apart the jaws of the release. The insufficient spring force provided in the early tests led to repeated hangups of several seconds in the release. It was at first thought that the firing solenoid was not operating properly. Various remedies were attempted. On one occasion the cable operating the release was tied to a length of pipe fastened to a standard B-7 shackle. During that test, either the nut on the stud holding the cable to the length of pipe backed off due to vibration or the differential contraction between the aircraft and the cable (due to temperature) allowed sufficient slack to occur in the cable so that premature release took place at 24,000 feet while still climbing to the desired altitude. The unit fell on the bomb doors. The doors were then opened and the bomb tore free, considerably damaging the doors. A landing with the doors open was made at San Bernardino Air Depot where the damaged doors were forced closed and a sheet of aluminum riveted across to hold them. The ship returned to Muroc and soon after flew to Wright Field for repairs. Thus ended the first series of tests.

New doors and three new engines were installed at Wright Field. The fault with the release system was found and installation corrected. Several releases were made on the ground.

The second series of tests was made at Muroc in June, 1944. No malfunction of the release system occurred, with the exception of a grounded bomb-door safety switch on one mission. This caused the bombing-circuit fuses to blow. Attempt was made to replace the fuses in the bomb bay in flight but they would not stay. It was necessary to bring the unit home and land. An unfused by-pass circuit around the door safety-switches was then installed, which circuit could be closed by means of a switch should the door switch failure occur in the future. The door switch installation on the early aircraft was poorly designed. It is believed no failures of door switches ever occurred in subsequent project aircraft where the door switch installation was considerably improved. However the by-pass circuit was included in the first group of project B-29's, and in the second group, which was used overseas, the bombing circuit was permanently wired around the door safety-switches.

After the June, 1944, tests it was learned that the weight of the final unit might be considerably greater than was at first thought. It was decided to use a more substantial release. In a meeting at Wright Field, Colonel Butler promoted the British type F release with the type G attachment; that release was accepted by the Project and its installation was started in the B-29 presently in use.

During a visit to the Project in August, 1944, by Colonels Wilson and Demler, it was decided that additional aircraft should be modified for use. Accordingly, Mr. Charles Speer was sent to the Glenn L. Martin-Nebraska Company, Omaha, Nebraska, to supervise the preparation of the engineering on the modifications required. S. H. Dike represented the Project at Omaha and engineered the special wiring and other additional provisions. The first modified aircraft was 42-65209; 17 aircraft were modified in all.

Figure 3 was for the F. M. bomb shape. For the Little Boy bomb, a different release mount was used. This mount was bolted to the lower side of the longitudinal beams. The Little Boy release mount is shown in position in Figure 4. This carrier frame was statically tested to two thirds of 7g vertically, 3g longitudinally and 2g laterally[1]. In a

[1]Glenn L. Martin-Nebraska Company Report E. L. R. Number N-511.

vertical load to test destruction the carrier failed at 62,000 pounds. Failure occurred in a gusset plate at the junction of the longitudinal and lateral beams. The gusset was redesigned and the destruction test repeated on the revised carrier. Failure occurred in the revised carrier at 85,000 pounds. It should be noted, however, that before this revision became effective, five aircraft were delivered with the weaker carrier; these were 42-65384 thru 387 and 44-27295. (See Glenn L. Martin-Nebraska Company Report E. L. R. Number N-12 for complete stress analysis of carrier and release mount.) (See Glenn L. Martin-Nebraska Company Drawing Numbers A-315 Change C, A-376 Change C, A-407 Change C, A-302 Change B, A-339 Change D and A-421 Change B for further details of carrier and release mounts.)

(2) Rework of Tunnel

In order to realize sufficient clearances, it was necessary to cut out part of the tunnel above the carrier for installation of the release. This rework of the tunnel is shown in Figure 5. A plastic window and two hand holes, fitted with removable plugs were made a part of this rework, and were installed for use in extreme emergency

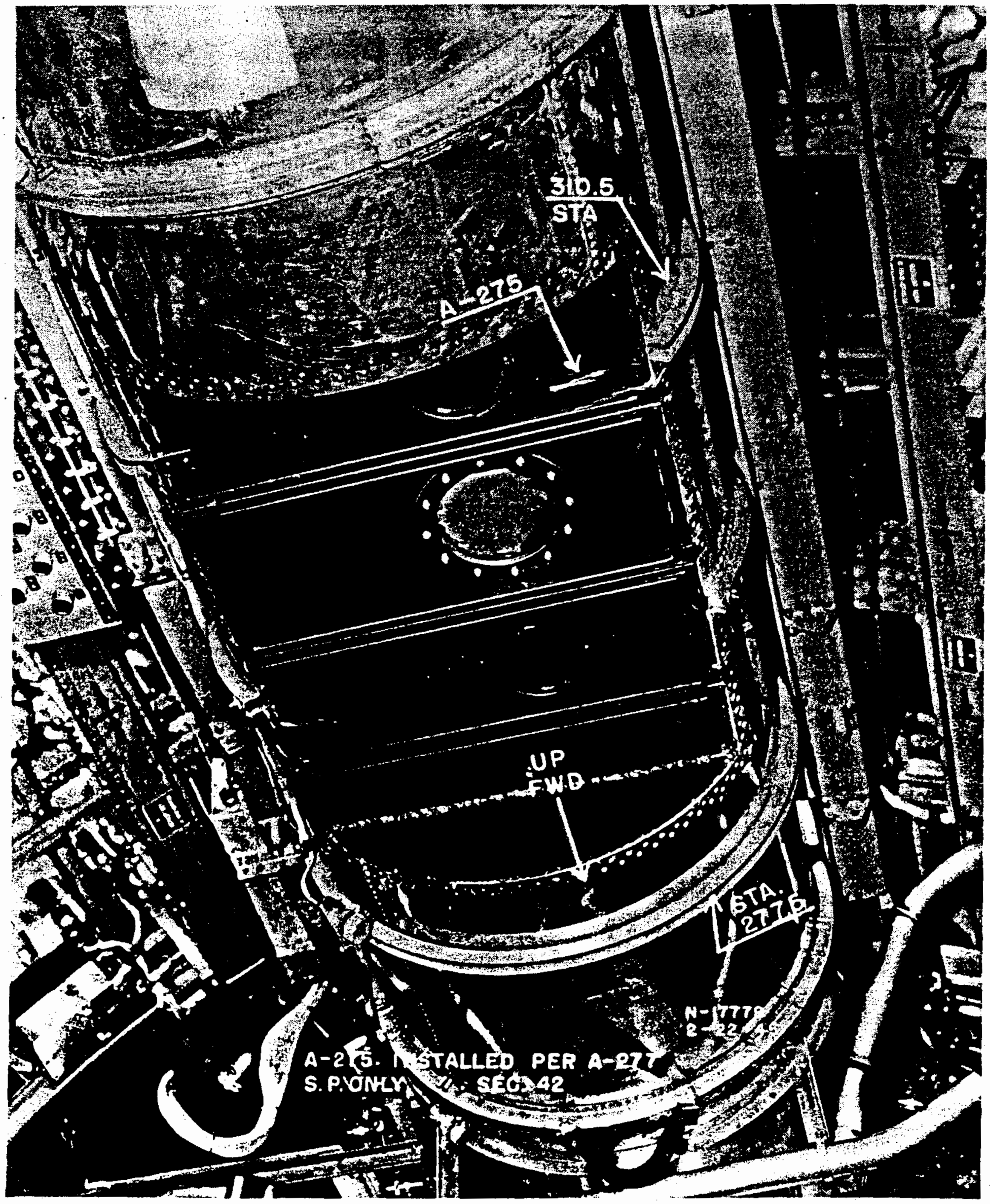
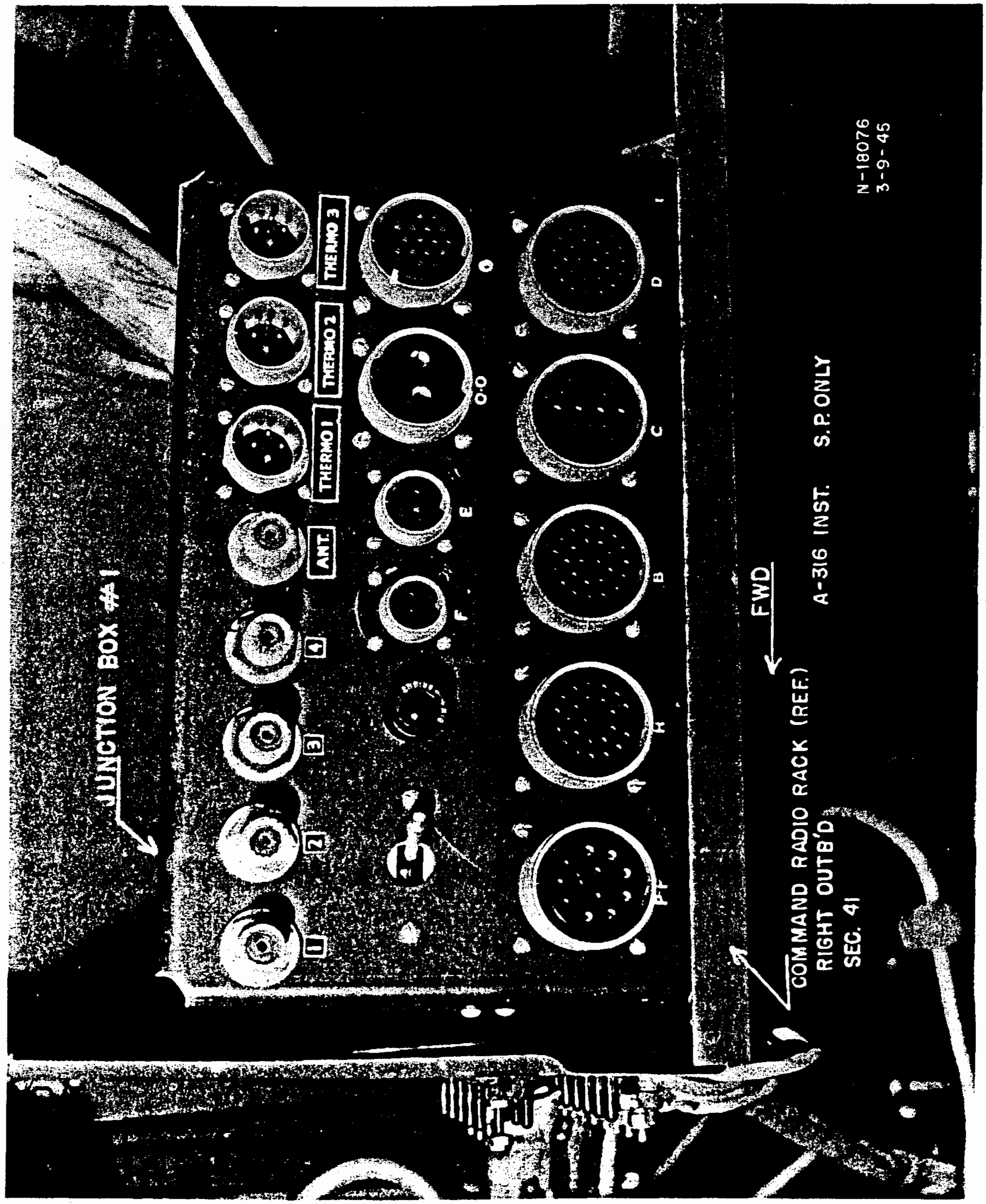


Figure 5


JUNCTION BOX #1
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THERMO 2
THERMO 3
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2
3
4
FWD
A-316 INST.
S.P. ONLY
COMMAND RADIO RACK (REF.)
RIGHT OUTB'D
SEC. 41
N-18076
3-9-45

Figure 9

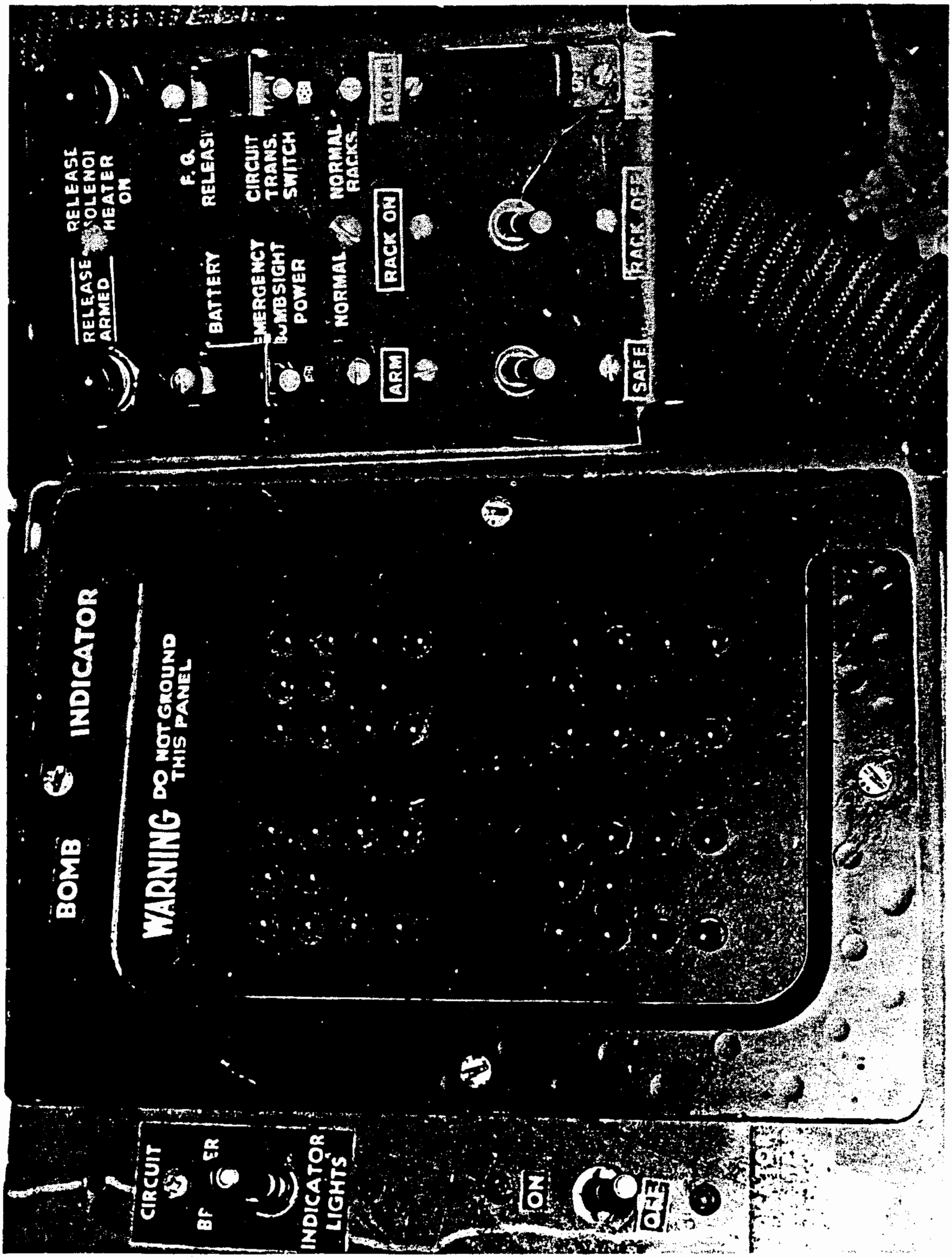
RELEASE ARMED
RELEASE SOLENOI HEATER ON
BATTERY
F.G. RELEASI
EMERGENCY BOMBSIGHT POWER
CIRCUIT TRANS. SWITCH
NORMAL
NORMAL RACKS
ARM
RACK ON
SAFE
RACK OFF
BOMB INDICATOR
WARNING DO NOT GROUND THIS PANEL
CIRCUIT
INDICATOR LIGHTS
ON
OFF

Figure 10

5.2-5 Mechanical Bomb Release Controls

Two levers were provided: One lever disengaged the release safety latch; the other operated the mechanical release lever on the Type F mechanism. Both cables were tube protected and ran down opposite sides of the bomb bay, and were terminated under spring tension in the box shown in Figure 11. Cables with adjustable slack were connected at this point and ran to the release and to the safety latch release sear.

5.2-6 Provision for Special Observational Equipment

(1) Special Antenna

The special antenna was used with the ARR-5 radio receiver installation and consisted of a removable quarter-wave rod. When in place, the antenna rod projected from the underside of the fuselage in the radar compartment; when not in use the antenna was stowed along the roof and a plug was placed in the hole. The installation was pressure tight. (See Drawing Number A-138 Sheet 1A.)

(2) Photocell installation

This consisted of a pressure tight plastic window in the underside of the radar compartment. A photocell was mounted in the plastic window and connected to Junction Box Number 3. This provision was never used and was later deleted.

(3) Equipment rack installation

The equipment rack housed the ARR-5 receiver and other equipment used by the airborne measurements group. An additional shelf was added overseas as a field modification. Junction Box Number 3 was mounted at the forward side of this rack.

CHAPTER 6

HISTORY OF PROJECT A AT TINIAN

by

N. F. Ramsey

6.1 INTRODUCTION

The Project A organization at Tinian consisted of the following:

Officer-in-Charge, Commodore W. S. Parsons USN; Scientific and Technical Deputy to Officer-in-Charge, N. F. Ramsey; Operations Officer and Military Alternate to Officer-in-Charge, Commander F. L. Ashworth, USN; Fat Man Assembly Team headed by Roger S. Warner Jr.; Little Boy Assembly Team headed by Commander Francis A. Birch, USNR; Fuzing Team headed by E. B. Doll; Electrical Detonator Team headed by Lt. Commander E. C. Stevenson, USNR; Pit Team headed by Phillip Morrison and C. P. Baker; Observation Team headed by Luis W. Alvarez and Bernard Waldman; Aircraft Ordnance Team headed by Sheldon H. Dike; and Special Consultants consisting of Robert Serber, W. G. Penney and Captain J. F. Nolan, AUS. The team leaders formed a Project Technical Committee under the chairmanship of Ramsey to coordinate technical matters and to recommend technical actions to Captain Parsons. The following persons were team members:

Agnew, Harold
Anderson, David L., Ensign
Bederson, Ben B., T/5
Bolstad, Milo M.
Brin, Raymond, T/Sgt.
Caleca, Vincent, T/Sgt.
Camac, Morton, T/Sgt.
Carlson, Edward G., T/Sgt.

Collins, Arthur, T/4
Dawson, Robert, T/Sgt.
Fortine, Frank J., T/Sgt.
Goodman, Walter, T/3
Harms, Donald C., T/3
Hopper, J. D., Lt.
Kupferberg, J., T/Sgt. Max
Johnston, Lawrence H.
Langer, Lawrence M.
Larkin, William J., T/Sgt.
Linschitz, Henry
Machen, Arthur B.
Mastick, Donald, Ensign
Matthews, Robert P., T/3

Miller, Victor A., Lt. (j.g.)
Motechko, L. L., T/3
Murphy, William L., T/Sgt.
Nooker, Eugene L., T/Sgt.
Olmstead, T. H.
O'Keefe, ~~G~~Bernard J., Ensign
Perlman, Ted
Prohs, Wesley R., Ensign
Reynolds, George, Ensign
Russ, Harlow W.
Schreiber, R. E.
Thorton, Gunnar, T/Sgt.
Tucker, J. L., Ensign
Zimmerli, Fred, T/4

Although not strictly members of Project A, the following were closely associated with the work of the Project: Rear Admiral W. R. Purnell, USN, representative of the Atomic Bomb Military Policy Committee; Brig. General T. F. Farrell, representative of Major General L. R. Groves; Colonel E. E. Kirkpatrick, alternate to General Farrell and the Officer in Charge of Construction; Colonel P. W. Tibbets, Commanding Officer of the 509th Composite Group; Lt. Colonel Peer de Silva, Commanding Officer of the First Technical Service Detachment, which served as administrative, security and housing organization for Project A; and Major Charles Begg, Commanding Officer of the First Ordnance Squadron, Special.

Although preliminary construction at Tinian began in April, 1945, intensified technical activities were not started until July. The first half of July was occupied with establishing and installing all of the technical facilities needed for assembly and test work at Tinian. After completion of these technical preparations, a Little Boy unit was assembled and, with the dropping of unit L1 on July 23, the Tinian base became fully operational for Little Boy tests. In the first test, a dummy Little Boy was fired in the air by radar fuze. Here, as in subsequent Tinian tests, excellent results were obtained. The second Little Boy, Unit L2, was dropped on July 24, and a third, Unit L5, on July 25. The only remaining phase of the Little Boy mission, and included as part of the test, was a check of facilities at Iwo Jima for emergency reloading of the bomb into another aircraft. Since the Iwo Jima facilities were not ready until July 29, this test was postponed until then. On July 29 a completely successful test of the Iwo Jima facilities was completed. The plane landed with the L6 Unit at Tinian so that it could be used in the final rehearsal maneuvers. On July 31 the plane with the L6 took off accompanied by two observation planes. The planes flew to Iwo Jima where a rendezvous was made, and then returned to Tinian where the bomb was dropped and observed to function properly. After the release of the bomb all three aircraft rehearsed the turning maneuvers which would be used in combat. With the completion of this test, all tests preliminary to combat delivery of a Little Boy with active material were completed.

The first Fat Man test, unit F13, was made on August 1, 1945. This unit used cast plaster blocks, electronic fuzing, eight electric detonators, Raytheon detonating unit and informers and smoke puffs on the operation of the detonators. The test showed that all essential components of the bomb functioned satisfactorily. A second inert Fat Man, F18, similar to F13, was prepared and loaded into a B-29 for drop on August 3. However, due to lack of information at Tinian of the results of the Wendover tests on the adequacy of the venting in the sealed Fat Man, the unit was unloaded and the barometric switches modified so that this information would be obtained on unit F18. In its modified form the F18 unit was dropped on August 5. All components functioned satisfactorily and the venting was adequate for the internal pressure to close a barometric switch set for 17,000 feet pressure altitude 17 seconds before impact. The only remaining preliminary Fat Man test was unit F33, a replica of the active unit, except for the lack of active material and the use of lower quality high explosive lens castings. The components for the F33 unit arrived at Tinian at 1230 on August 2 and preliminary assembly was begun the same day. Although the F33 unit was fully assembled by August 5, it was not dropped until August 8 due to absence of key crews and aircraft on the final Little Boy mission. A test was then conducted as a final rehearsal for the delivery of the first live Fat Man. Both the rehearsal operation and the detonation of the unit were completely satisfactory.

On July 26, the U^{235} projectile for the Little Boy was delivered by the cruiser INDIANAPOLIS. The U^{235} target insert arrived in three separate parts in three, otherwise empty, Air Transport Command C-54's during the evening of July 28 to 29. All three had arrived by 0200 July 29. Since the earliest date previously discussed for combat delivery of the Fat Man was August 5 (at one time the official date was August 15). Parsons and Ramsey cabled General Groves for permission to drop the first active unit perhaps as early as August 1, with August 2 being more probable since poor weather was forecast for August 1.

Although the active Little Boy unit, No. L11, was completely ready in plenty of time for an August 2 delivery, the weather was unfavorable. The first, second, third, and fourth of August were spent in impatient waiting for good weather. Finally, on the morning of August 5 word was received that the weather should be good on August 6. At 1400 on August 5 General Lemay officially confirmed that the mission would take place on August 6.

The Little Boy was loaded onto its transporting trailer at 1400 on August 5 and, with an accompanying battery of photographers, was taken to the loading pit. The B-29 was backed over the pit at 1500 and the L11 unit loaded shortly thereafter. The aircraft was then taxied to its hard stand where final testing of the unit was completed. By 1800 all was ready. Between then and take-off, the aircraft was under continuous watch both by a military guard and by representatives of the key technical groups.

Final briefing was at 0000 of August 6. Following this, and an early breakfast, the crews assembled at their aircraft. There, amid brilliant floodlights, pictures were taken and retaken by still and motion picture photographers (as though for a Hollywood premiere). For the mission Colonel P. W. Tibbets was pilot of the B-29 (named the Enola Gay) which carried the bomb, Major Thomas Ferebee was bombardier, Captain W. S Parsons was bomb commander, and Lt. Morris Jepson was electronics test officer for the bomb. L. Alvarez, Bernard Waldman, Harold Agnew and Larry Johnston rode in the accompanying observation aircraft.

The progress of the mission is best described in the log which Captain Parsons kept during the flight:

Captain Parsons' log:

August 6, 1945

0245	Take off
0300	Started final loading of gun
0315	Finished loading
0605	Headed for Empire from Iwo Jima
0730	Red plugs in (these plugs armed the bomb so it would detonate if released)
0741	Started climb
	Weather report received that weather over primary and tertiary targets was good but not over secondary target.
0838	Leveled off at 32,700 feet 30,750 IA in 31060' True (Nav Log)
0847	All Archies (electronic fuzes) tested to be O.K.
0904	Course west
0909	Target (Hiroshima) in sight
0915 1/2	Dropped bomb (originally scheduled time was 0915)
	Flash followed by two slaps on plane. Huge cloud.
1000	Still in sight of cloud which must be over 40,000 high
1003	Fighter reported
1041	Lost sight of cloud 363 miles from Hiroshima with the aircraft being 26,000 feet high. 25,550 IA

The crews of the strike and observation aircraft reported that 5 minutes after release a low 3 mile diameter dark grey cloud hung over the center of Hiroshima, out of the center of this a white column of smoke rose to a height of 35,000 feet with the top of the cloud being considerably enlarged.

Four hours after the strike, photo-reconnaissance planes found that most of the city of Hiroshima was still obscured by the cloud created by the explosion although fires could be seen around the edges. The following day excellent pictures were obtained showing the tremendous magnitude of the power of a single atomic bomb, which completely destroyed 60 percent of the city of Hiroshima.

The first Fat Man with active material, unit F31, was originally scheduled for dropping on August 11 local time (at one time the schedule called for August 20). However, by August 7 it became apparent that the schedule could be advanced to August 10. When Parsons and Ramsey proposed this change to Tibbets, he expressed regret that the schedule could not be advanced two days instead of only one since good weather was forecast for August 9 and the five succeeding days were expected to be bad. It was finally agreed that Project A would try to be ready for August 9 provided all concerned understood that the advancement of the date by two full days introduced a large measure of uncertainty into the probability of meeting such a drastically revised schedule. However, all went well with the assembly and by 2200 of August 8 the unit was loaded and fully checked.

The strike plane and two observing planes took off at 0347 local time on August 9. Major C. W. Sweeney was pilot of the strike ship, Captain K. K. Beahan was bombardier, Commander F. L. Ashworth was bomb Commander, and Lt. Philip Barnes was electronics test Officer. This mission was as eventful as the Hiroshima mission was operationally routine.

Due to bad weather between Tinian and Iwo Jima, a preliminary rendezvous was not planned for three aircraft at Iwo Jima, and instead, the briefed route to the Japanese Empire was from Tinian direct to Yakoshima or Kyushu. The briefed cruising altitude was 17,000 feet. Commander Ashworth's log for the trip is as follows:

Commander Ashworth's log:

0347	Take off
0400	Changed green plugs to red prior to pressurizing
0500	Charged detonator condensers to test leakage. Satisfactory.
0900	Arrived rendezvous point at Yakoshima and circled awaiting accompanying aircraft.
0920	One B-29 sighted and joined in formation
0950	Departed from Yakoshima proceeding to primary target Kokura having failed to rendezvous with second B-29. The weather reports received by radio indicated good weather at Kokura (3/10 low clouds, no intermediate or high clouds, and forecast of improving conditions). The weather reports for Nagasaki were good but increasing cloudiness was forecast. For this reason the primary target was selected.

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1044 Arrived initial point and started run on target. Target was obscured by heavy ground haze and smoke. Two additional runs were made hoping that the target might be picked up after closer observation. However, at no time was the aiming point seen. It was then decided to proceed to Nagasaki; approximately 45 minutes spent in the primary target area.

1150 Arrived in Nagasaki target area. Approach to target was entirely by radar. At 1158 the bomb was dropped after a twenty second visual bombing run. The bomb functioned normally in all respects.

1205 Departed for Okinawa after having circled smoke column. Lack of available gasoline caused by an inoperative bomb tank booster pump forced decision to land at Okinawa before returning to Tinian.

1351 Landed at Yontan Field, Okinawa

1706 Departed Okinawa for Tinian

2245 Landed at Tinian

Due to bad weather, good photo-reconnaissance pictures were not obtained until almost a week after the Nagasaki mission. These showed that the bomb detonated somewhat north of the Mitsubishi Steel and Arm Works. All other factories and buildings on the Urakami River from the Nakajima Gawa River through the Mitsubishi Urakami Ordnance Plant were destroyed. The distance from the northernmost factory that was destroyed to the southern boundary of pletely different model and one much more difficult to assemble. The success of the combat use of the atomic bomb is best summarized by the fact that Japan began surrender negotiations four days after the use of the first atomic bomb.

UNIVERSITY OF CALIFORNIA
LOS ALAMOS SCIENTIFIC LABORATORY
(CONTRACT W-7405-ENG-36)
P. O. Box 1663
Los Alamos, New Mexico

IN REPLY REFER TO: D-DOC-5099

January 24, 1951

"When separated from enclosures, handle this document as unclassified (Insert proper classification)"

General Manager
U. S. Atomic Energy Commission
1901 Constitution Avenue, N.W.
Washington 25, D.C.

Attention: Mrs. J. O'Leary

Dear Mrs. O'Leary:

Enclosed herewith are copies 5,6 and 7,8, of report LA-1161 which are being sent to your office for transmittal to the Division of Military Application for their review after accountability has been established by your office.

We feel that this report is not distributable according to Report M-3679, "Standard Distribution Lists", because it contains weapon data.

Very truly yours,
Helen F. Challenger
Helen F. Challenger
Document Room

Enc. 5 docs.
rec. #36268 thru 36271

SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

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SESSION XI

ARMING, FIRING, AND INITIATION

- •POWER SUPPLIES
- •FIRING SETS
- •NEUTRON SOURCES

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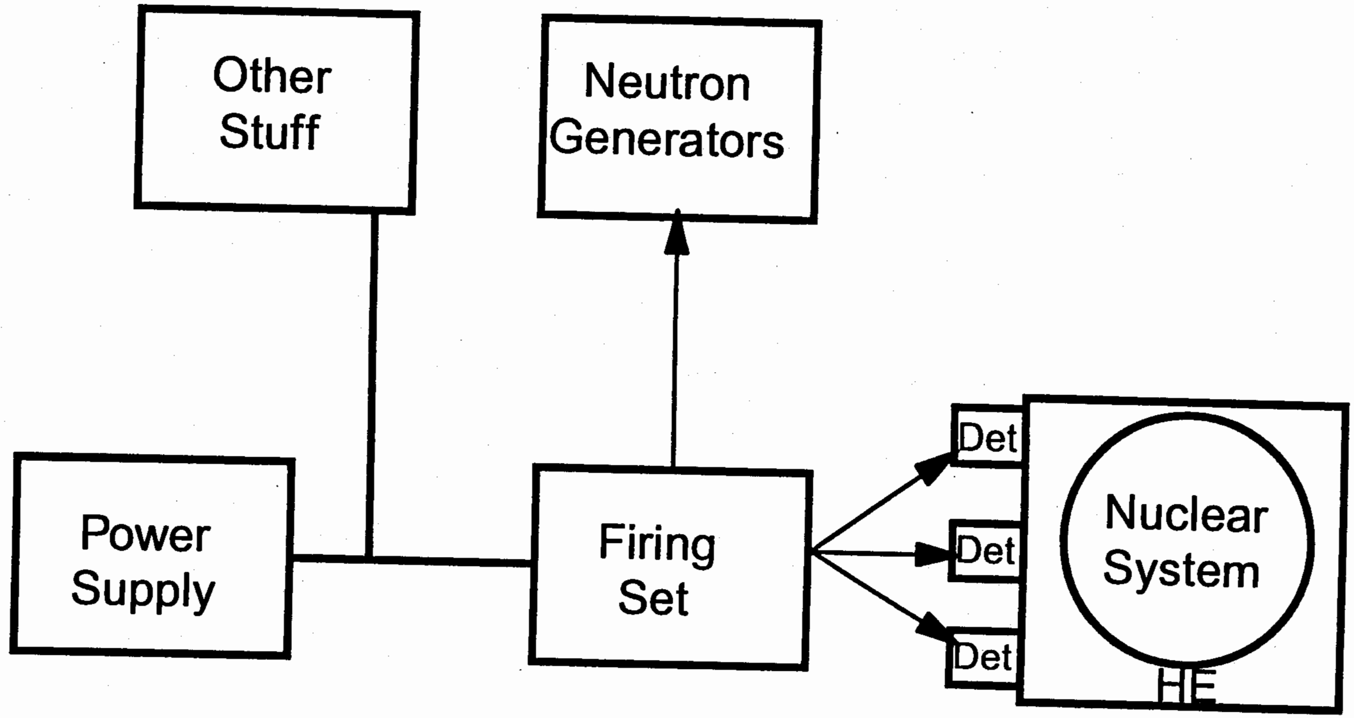

Bomb--Yes
WH--Maybe

Nuclear Weapon

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Assumptions

Understand Basic Concepts For:

- Detonators
- Initiation Requirements
- Fuzing
- Safety
- Use Control

Implementation of Concepts Will Be Described as Part of This Session

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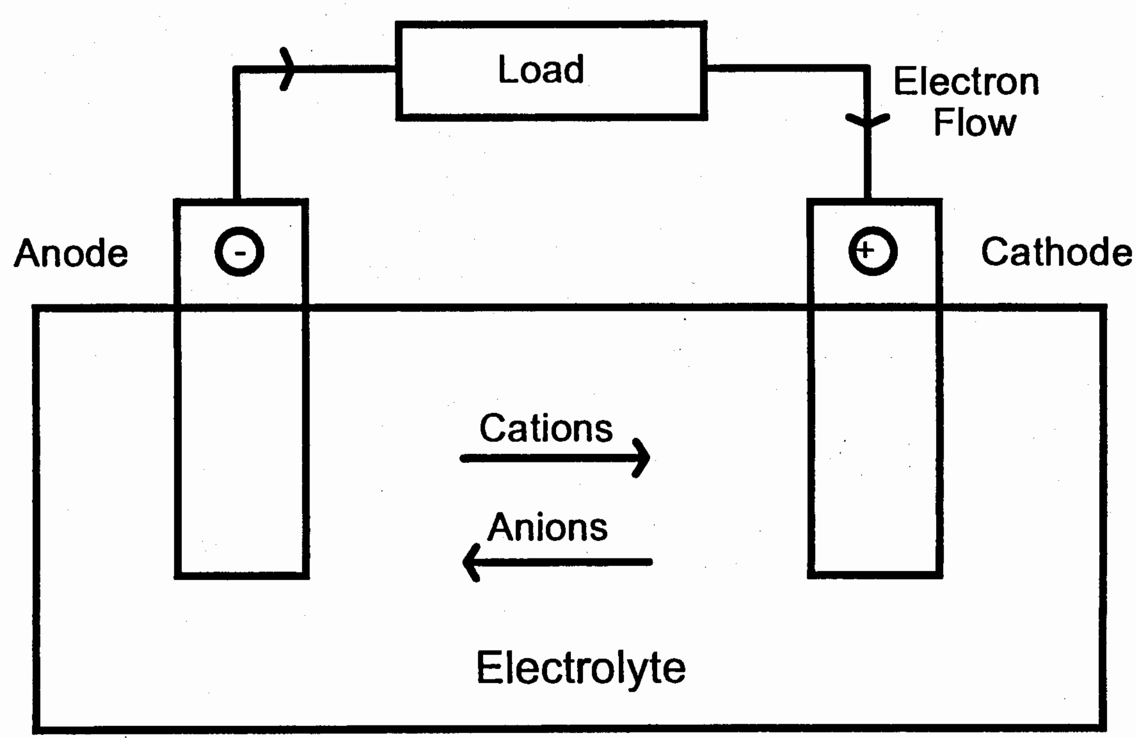
Power Supplies

- Battery Technologies
- Evolution of Battery Development

Battery Cell
(During Discharge)



Nomenclature

Primary - Life ends upon discharge

Examples: Zinc-Carbon - Flashlight

Alkaline Manganese - Flashlight

Zinc-Silver Oxide - Missile guidance system
- Sandia JTA

Lithium - High energy density applications (such as nuclear weapons)

Secondary - Rechargeable

Examples: Lead-Acid - Automobile

Nickel-Cadmium - Portable appliances
- Sandia PAL Controllers

Iron-Nickel - Electric vehicles

Zinc-Silver Oxide - Portable military equipment

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Nomenclature

Dry Cells - Aqueous electrolyte has been immobilized by use of gelling agents

Solid State Cells - Solid electrolyte has conductance wholly due to ionic motion with solid lattice

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Nomenclature

Reserve Battery - Any battery which will not deliver current until activated, e.g., by adding electrolyte or melting electrolyte

Thermal Battery - A reserve battery activated by raising the temperature to melt the electrolyte, which is a salt mixture - used extensively in nuclear weapons

Depolarizer Pad - The active cathode material which is reduced electrochemically during battery discharge

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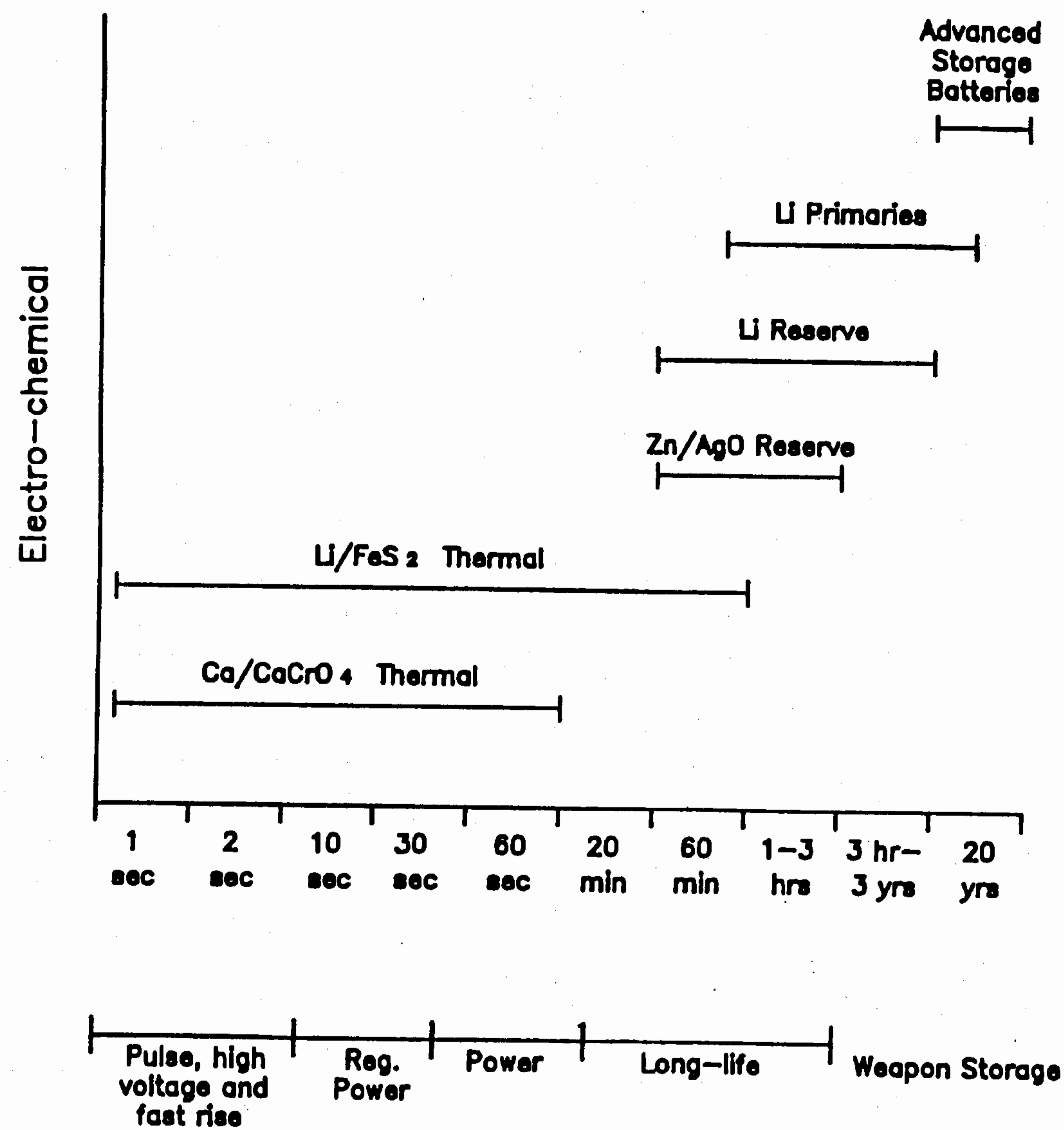
Nuclear Weapon Batteries

Little Boy	NT—6	Lead Acid	1945
Fat Man	ER—12	Lead Acid	
MK 4, 5, 6, 7	MC193	Nickel—Cadmium	1953
MK 12	MC271	Silver—Zinc	
MK 15	MC473	Thermal Ca—$CaCrO_4$	1955
Multiple	Multiple	Thermal Li—FeS_2	1970's
All New Designs		Thermal Li—FeS_2	Present

NOTE: JTA's, controllers, and support equipment may utilize designs other than thermal batteries

Battery Technologies



Reactions

$Ca/CaCrO_4$

- **Electrochemical:**

Anode – $Ca \xrightarrow{Li^+} CaLi_2 \rightarrow Ca^{2+}$(double salt)$\downarrow + 2e^-$

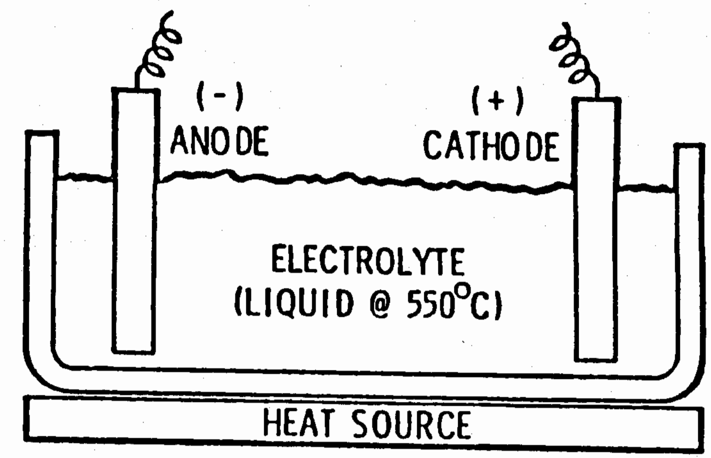
Cathode – $CrO_4^{2-} + 3e^- \rightarrow$ (soluble intermediates) $\xrightarrow{Li^+}$ $Ca_6Cr_4O_xSiCl_2$, $Li_xCa_yCrO_4$, $Li_xCr_yO_z$, CaO

- **Identifiable Side Reactions:**

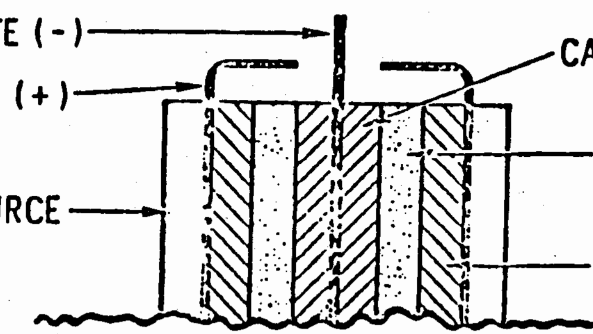
$4Ca + SiO_2 \rightarrow 2CaO + Ca_2Si + (-660\ cal/g)$

$3Ca + 2CaCrO_4 + 2LiCl \rightarrow 2Ca_2CrO_4Cl + CaLi_2 + (-1770\ cal/g)$

CONVENTIONAL CELL



ANODE - CALCIUM METAL ON IRON SUBSTRATE
CATHODE - CALCIUM CHROMATE (DEPOLARIZER)
ELECTROLYTE - LITHIUM CHLORIDE, POTASSIUM CHLORIDE
HEAT SOURCE - ZIRCONIUM-BARIUM CHROMATE
CELL CASE - IRON



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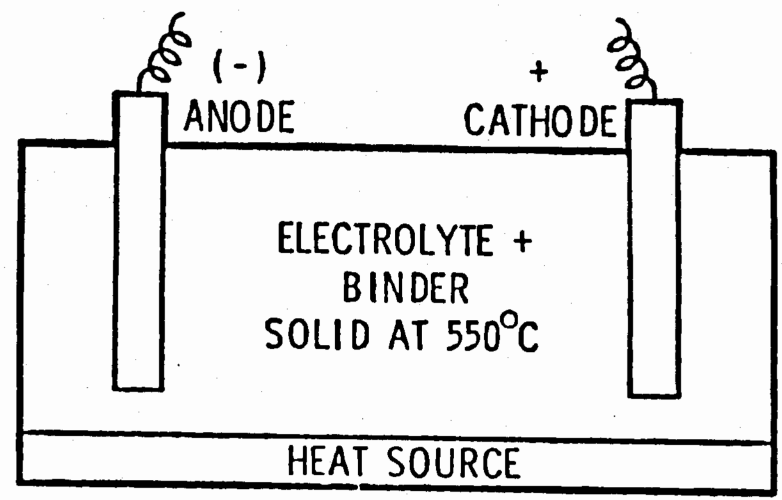
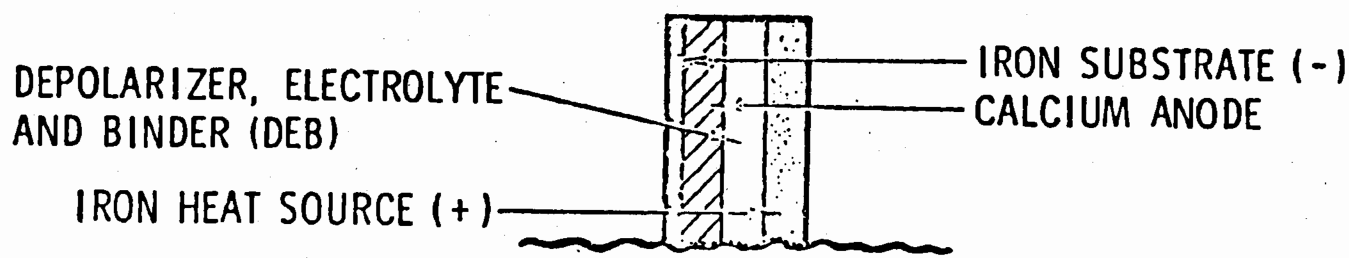
NEW PELLETIZED CELL



ANODE	- CALCIUM ON IRON SUBSTRATE
CATHODE	- CALCIUM CHROMATE (depolarizer) } DEB
ELECTROLYTE	- LITHIUM CHLORIDE, POTASSIUM CHLORIDE + SiO_2 BINDER } DEB
HEAT SOURCE	- IRON-POTASSIUM PERCHLORATE DISC
CELL CASE	- NONE



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WEAPONS/WEAPON APPLICATIONS

WEAPON*	APPLICATION	SERVICE
FATMAN	BOMB	AF
LITTLEBOY	BOMB	AF
Mk III	BOMB	AF
Mk 4	BOMB	AF
T-4	ADM	A
Mk 5	BOMB	AF,N
Mk 5	MATADOR	AF
Mk 5	REGULUS I	N
Mk 6	BOMB	AF
Mk 7	BOMB	AF,N
Mk 7	HONEST JOHN	A
Mk 7	CORPORAL	A
Mk 7	BOAR	N
Mk 7	BETTY	N
Mk 7	ADM	A
Mk 7	NIKE HERCULES	A
Mk 8	BOMB	N
Mk 9	280-mm AFAP	A
Mk 11	BOMB	N

*Absence of entry indicates system not fielded

WEAPON	APPLICATION	SERVICE
Mk 12	BOMB	AF,N
Mk 14	BOMB	AF
Mk 15	BOMB	AF,N
Mk 17	BOMB	AF
Mk 18	BOMB	AF,N
Mk19	280-mm AFAP	A
Mk21	BOMB	AF
Mk23	16" AFAP	N
B24	BOMB	AF
W25	GENIE	AF
B27	BOMB	N
W27	REGULUS I	N
B28	BOMB	AF,N
W28	HOUNDDOG	AF
W28	MACE	AF
W30	TALOS	N
W30	ADM	A
W31	HONEST JOHN	A
W31	NIKE HERCULES	A
W31	ADM	A
W33	8" PROJECTILE	A,N

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WEAPON	APPLICATION	SERVICE
W34	LULU	N
W34	ASTOR	N
B34	HOTPOINT	N
B36	BOMB	AF
W38	ATLAS	AF
W38	TITAN I	AF
B39	BOMB	AF,N
W39	B-58 pod	AF
W39	REDSTONE	A
W39	SNARK	AF
W40	BOMARC	AF
W40	LACROSSE	A
B41	BOMB	AF
B43	BOMB	N,AF
W44	ASROC	N
W45	BULLPUP	N
W45	TERRIER	N
W45	LITTLE JOHN	A
W45	MADM	A
W47	POLARIS	N
W48	155-mm AFAP	A,N

WEAPON	APPLICATION	SERVICE
W70	LANCE	A
W71	SPARTAN	A
W72	WALLEYE	AF
W76	TRIDENT I	N
W78	MINUTEMAN III	AF
W79	8" AFAP	A,N
W80	SLCM	N
W80	ALCM	AF
B83	BOMB	AF
W84	GLCM	AF
W85	PERSHING II	A
W87	PEACEKEEPER ICBM	AF
W88	TRIDENT II	N

The Gang of Four

$^{238}U_{92}$ % in nature - 99.27 When the $^{238}U_{92}$ is extracted, it is called depleted ^{238}U or TUBALLOY or D38 (from UK WWII effort - TUBE ALLOY). Will fission but not fissile Physically separated	^{239}Pu % in nature - essentially zero (mine in South Africa) Made in Reactor: $N + {}^{238}U = {}^{239}Pu$
^{235}U % in nature - 00.73 Concentrated to 93.5%. Called ORALLOY for Oak Ridge Alloy	^{240}Pu % in nature - essentially zero Made by reactor. If you leave the ^{239}Pu in "too long," it will absorb a $N \rightarrow {}^{240}Pu$. Spontaneously fissions (originally a problem for pre-ignition).

CALCULATION OF ENERGY RELEASE

$$_{92}U^{235} + {}_{o}n^{1} \longrightarrow {}_{42}Mo^{95} + {}_{57}La^{139} \quad 7\,{}_{-1}e^{o} + 2\,{}_{o}n^{1}$$

235.0439		94.905837
1.0087		138.906400
		.003850
		2.017340
236.0526 amu	⟶	235.8334 amu

MASS DEFECT OF .219 amu

n = 1.00867 amu
p = 1.00728 amu
e = .00055 amu

$$(.219 \text{ amu}) \quad (931.4 \ \frac{\text{MeV}}{\text{amu}}) \simeq 204 \text{ MeV}$$

THE EXAMPLE STARTED WITH

$$_{54}Xe^{139} \xrightarrow{3\beta} {}_{57}La^{139} \quad \text{AND} \quad {}_{38}SR^{95} \xrightarrow{4\beta} {}_{42}Mo^{95}$$

FISSION CHAIN

THEORETICAL FISSION ENERGY

- THERE ARE $\frac{6.025X10^{23}}{235.0439}$ ATOMS PER GRAM OF $_{92}U^{235}$
- THEREFORE, 1 kg OF $_{92}U^{235}$ HAS $2.5634X10^{24}$ ATOMS
- HENCE, @ 180 MeV PER FISSION 1 kg OF $_{92}U^{235}$ WOULD PRODUCE
- $4.6141x10^{26}$ MeV IF EACH ATOM WERE FISSIONED.
- CONVERTING TO KILOTONS
- $(4.6141X10^{26}$ MeV) $(3.824X10^{-26}$ $\frac{kT}{MeV}$) = 18 kT

T

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FACTORS AFFECTING CRITICAL MASS

- GEOMETRY
- AMOUNT OF MATERIAL
- TYPE OF MATERIAL
- PURITY OF MATERIAL
- SURROUNDING MATERIAL
- DENSITY

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WEAPONS MATERIALS

Plutonium 239 = Pu^{239} = P^{239}_{94} = Pu

Made by placing natural uranium as the target in a reactor. Weapons grade Pu = having less than 6% Pu^{240}.

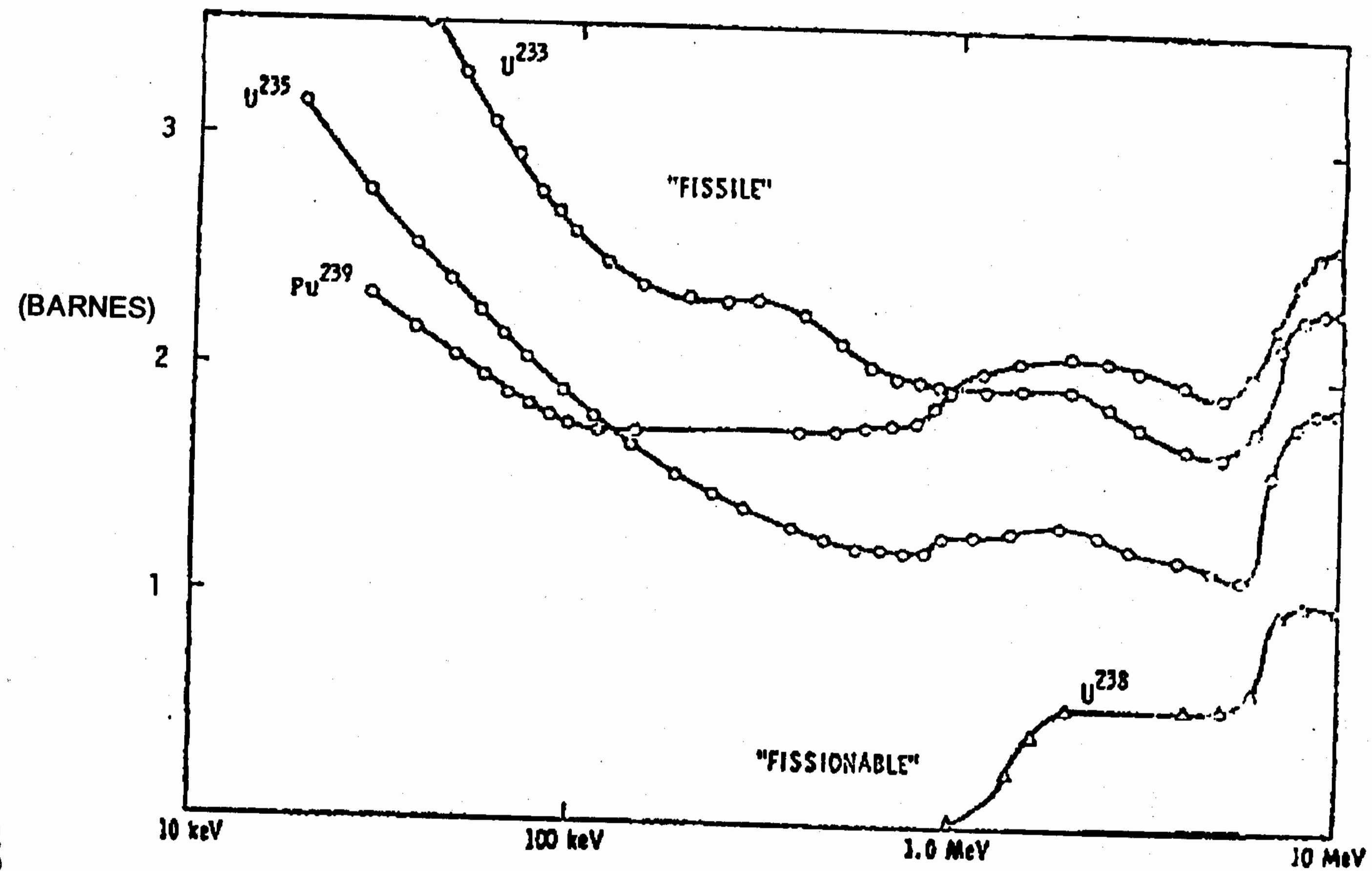
Oralloy = Oy = Uranium that has been enriched to 93 .X$^{\%}$ U^{235}_{92}

Tuballoy -- Tu -- natural uranium but also includes depleted uranium (i.e. U^{238})

Tritium = H^3_1 = T^3 = T

DoD (b)(?)

FISSION CROSS SECTIONS



INCIDENT NEUTRON ENERGY

NOTE: The thermal neutron energy is not on the chart

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TEMPERATURE EXPRESSED IN kT (ENERGY)

where K is Boltzmann Constant $\left\{ \begin{array}{l} 1.38X10^{-16}\ \text{erg}/\ ^{\circ}K \\ 8.62X10^{-8}\ \text{keV}/\ ^{\circ}K \end{array} \right.$

$T\ (\text{in keV}) = 8.62X10^{-8}\ T\ (\text{in }^{\circ}\text{Kelvin})$

Temperature of 1 keV = $1.16x10^{7}$ degrees Kelvin

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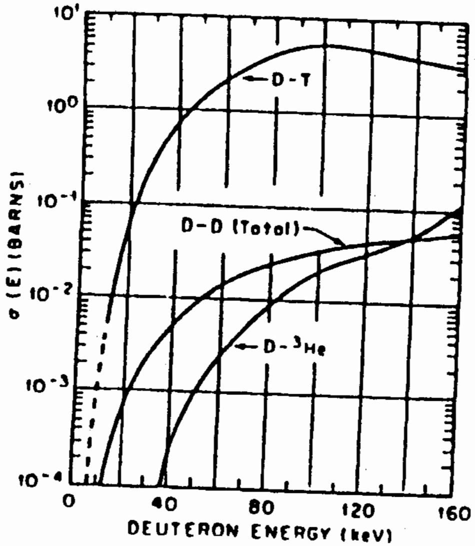
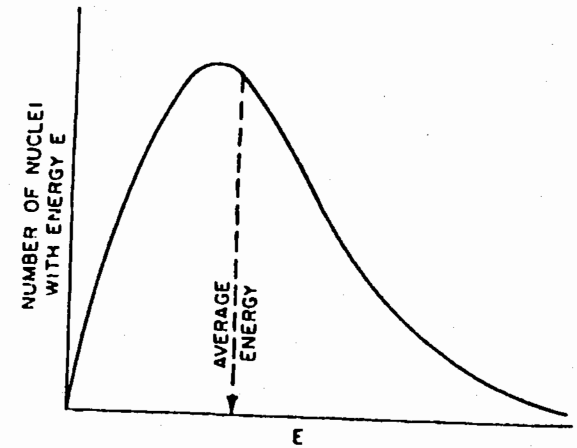
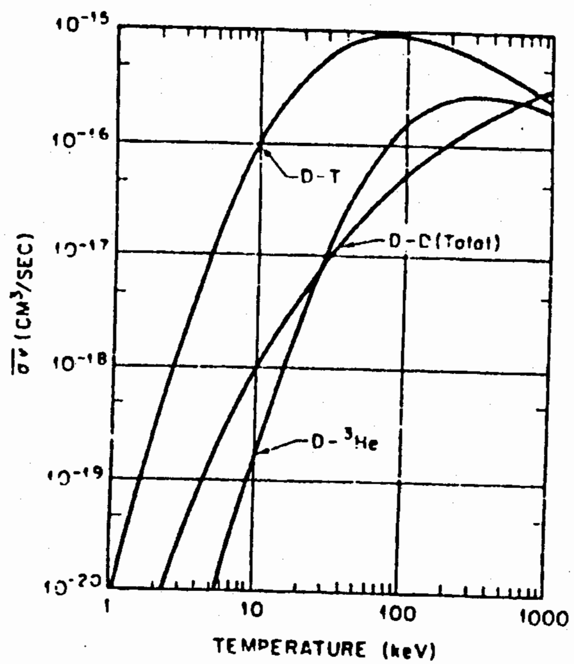


σ (E) (BARNS)
10¹
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
D-T
D-D (Total)
D-³He
0
40
80
120
160
DEUTERON ENERGY (keV)



NUMBER OF NUCLEI WITH ENERGY E
AVERAGE ENERGY
E



σv (CM³/SEC)
10⁻¹⁵
10⁻¹⁶
10⁻¹⁷
10⁻¹⁸
10⁻¹⁹
10⁻²⁰
D-T
D-D (Total)
D-³He
1
10
100
1000
TEMPERATURE (keV)

Thermal Nuclear Plasma

AT FUSION TEMPERATURES, WE HAVE A PLASMA OF IONS (NUCLEI AND ELECTRONS).

$$\text{ENERGY} = aT_{(ion)} + bT_{(electron)} + cT^4_{(radiation)}$$

IF PLASMA IS IN THERMODYNAMIC EQUILIBRIUM THE THREE TEMPERATURES ARE EQUAL ➡ AT HIGH TEMPERATURES, RADIATION WILL DOMINATE.

REFERENCES

AN INTRODUCTION TO NUCLEAR WEAPONS; WASH 1037 REVISED; SRD (N) SIGMA 1 *etc.*; GLASSTONE AND REDMAN.

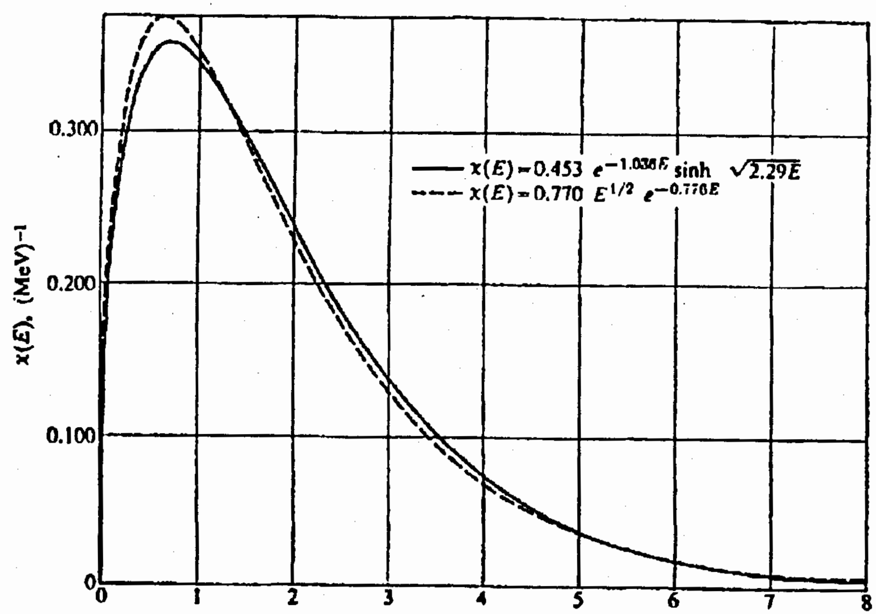
SOURCE BOOK ON ATOMIC ENERGY; GLASSTONE; UNC 3rd EDITION

BASIC NUCLEAR PHYSICS; INTERSERVICE NUCLEAR WEAPONS SCHOOL

DNA PUBLICATIONS — TECHNOLOGY ANALYSIS REPORT

SANDIA, LLL, LANL TECHNOLOGY REPORTS

Fission Neutron Energy Spectrum

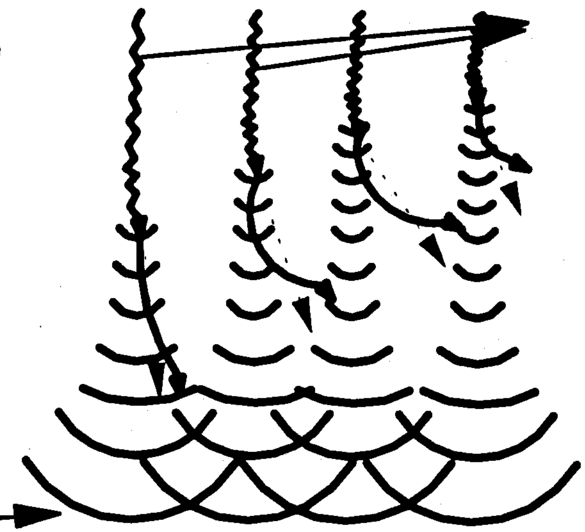


Neutron Energy (MeV)

Reference: Lamarsh, 1966

HIGH ALTITUDE EMP

ELECTROMAGNETIC PULSE



KEY Points

1. Each γ gives a downward traveling compton electron.
2. The electrons are turned by the earth's magnetic field.
3. The realistic electrons radiate energy downward.
4. The γ's and EMP radiation travel at the same speed.
   This leads to constructive interference of radiation from all electrons.

Nuclear Targeting

- Through intelligence data, the targets have a vulnerability number associated with it that allows the DoD to assign a weapon.
- Vulnerability Number (VN)

  XXPA   XXQA

  First 2 digits are related to the amount of pressure:
  - P = over pressure (smash)
  - Q = dynamic pressure (winds)
  - A = adjustment for yield (tables geared to 20 KT)
- A typical VN:

  Airfield = 12 P0 ~ 10 psi

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Cast explosives: names and formulations.

Explosive[a]	TNT	RDX	Other ingredients	
	Formulation (wt%)[b]			
Baratol	24		$Ba(NO_3)_2$	76
Boracitol	40		Boric Acid	60
*Comp B, Grade A[c]	36	63	Wax	1
Comp B-3	40	60		
*Cyclotol[d]	25	75		
H-6	30	45	Wax	5
			Al	20
			$CaCl_2$	0.5
*Octol	25		HMX	75
*Pentolite[d]	50		PETN	50
Tritonal	80		Al	20

[a]Properties of materials marked with asterisks are summarized in data sheets (Section IV).

[b]The weight percent values given in the table are nominal and subject to some variation.

[c]Comp B, Grade A is formulated as a 60/40 RDX/TNT mixture, but high-quality castings usually are higher in RDX content due to the removal of a TNT-rich section at the top of the casting.

[d]There are several cyclotols and pentolites. The most common cyclotol is RDX/TNT 75/25. The most common pentolite is PETN/TNT 50/50.

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Plastic-bonded explosives: Names and formulations.

Explosive[a]	Other ingredients	Formulation: Ingredient	wt%	Color
*LX-04-1	PBHV-85/15	HMX	85	Yellow
		Viton A	15	
*LX-07-2	RX-04-BA	HMX	90	Orange
		Viton A	10	
*LX-09-0	RX-09-CB	HMX	93	Purple
		pDNPA	4.6	
		FEFO	2.4	
LX-09-1		HMX	93.3	Purple
		pDNPA	4.4	
		FEFO	2.3	
*LX-10-0	RX-04-DE	HMX	95	Blue-green spots on white
		Viton A	5	
LX-10-1		HMX	94.5	Blue-green spots on white
		Viton A	4.5	
*LX-11-0	RX-04-PI	HMX	80	White
		Viton A	20	
*LX-14-0		HMX	95.5	Violet spots on white
		Estane 5702-FI		4.5
*PBX-9007	PBX-9007 Type B	RDX	90	White or mottled gray[b]
		Polystyrene	9.1	
		Di(2-ethyl-hexyl)-phthalate	0.5	

Plastic-bonded explosives: Names and formulations. (cont.)

		Formulation		
		Rosin	0.4	
*PBX-9010		RDX	90	White
		Kel-F	10	
*PBX-9011	X-0008	HMX	90	Off-white
		Estane 5740-X2		
*PBX-9205		RDX	92	White
		Polystyrene	6	
		Di(2-ethyl-hexyl)-phthalate	2	
*PBX-9404	PBX-9404-03	HMX	94	White or blue
		NC (12.0% N)	3	
		Tris (B-chloro-ehtyl)-phosphate	3	
*PBX-9407		RDX	94	White or black[b]
		Exon 461		6
*PBX-9501		HMX	95	White
		Estane	2.5	
		BDNPA	1.25	
		BDNPF	1.25	
PBX-9502		TATB	.05 Kel F	
LX-17		TATB	.075 Kel F	

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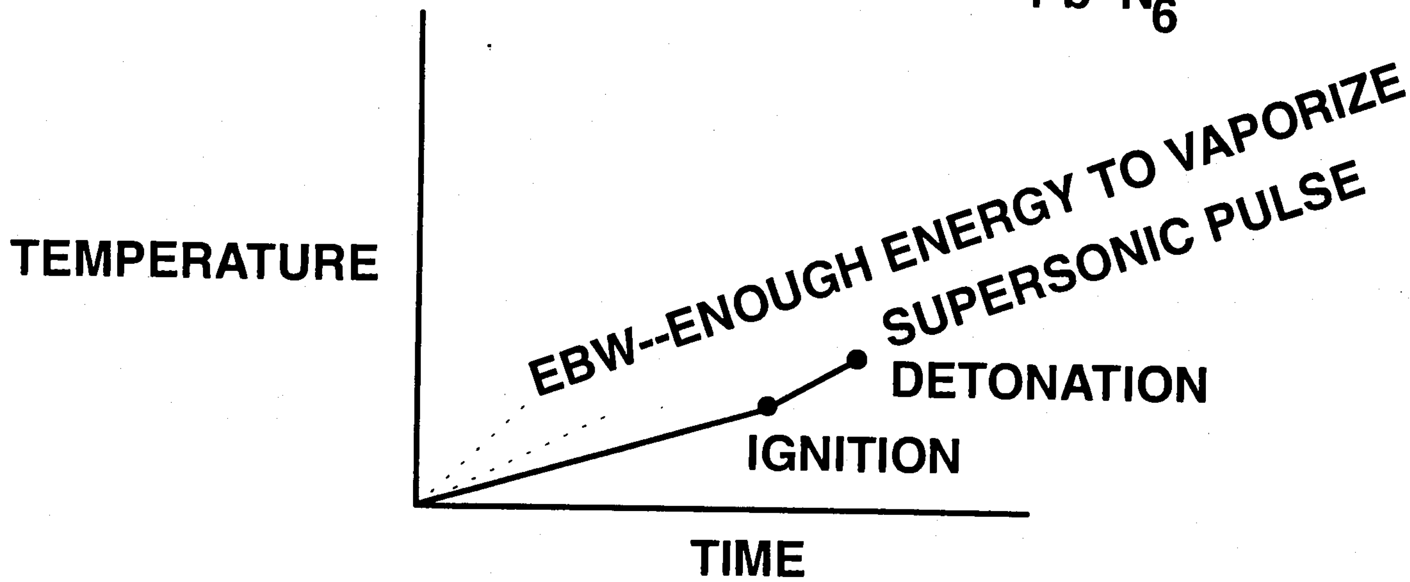
LEAD AZIDE
$Pb\ N_6$



EBW (EXPLODING BRIDGEWIRE) EVOLVED

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REFERENCES

- AN INTRODUCTION TO NUCLEAR WEAPONS; WASH 1037 REVISED; GLASSTONE, JUNE 1972
- PROPERTIES OF CHEMICAL EXPLOSIVES AND EXPLOSIVE SIMULANTS; LLL JULY 31, 1974, DOBRATZ UCRL - 51319, REV 1
- SENSITIVITY OF INITIATION-SYSTEM DETONATORS: REVIEW OF CURRENT AND ADVANCED TECHNOLOGIES; R. E. SETCHELL; SAND91-1590

[redacted] UNCLASSIFIED

REFERENCES

- AN INTRODUCTION TO NUCLEAR WEAPONS; WASH 1037 REVISED, GLASSTONE, JUNE 1972
- SOURCE BOOK ON ATOMIC ENERGY; GLASSTONE, 3rd EDITION
- NUCLEAR TEST SUMMARY TRINITY — HARDTACK DASA 1220; RS3141/10349
- VARIOUS WEAPON DEVELOPMENT REPORTS

MMSC Demilitarization/Sanitization

Part Nomenclature	Demilitarization	Sanitization	Render Safe	Method
Actuators/Squibs	Yes	No/Yes	Yes	Fire or explosive disposal (Some Use Control items may require sanitization)
Connectors	No	No/Yes	No	None (Unless Rad hardening potting used, then sanitization required)
Detonators and Cable Assemblies	Yes	Yes	Yes	Fire - Shred cable/crush header or explosive disposal (protect # info)
Foams, cushions, compression pads, desiccants, plastics, etc.	No	No/Yes	No	None (Shred, melt, or burn if show classified contours or shock mitigation info.)
Mechanical Hardware (O-rings, brackets, bolts, cover plates, rings, etc.	No	No	No	None (Part identifier removed if association makes classified)
Neutron Generator, Electronic	Yes	Yes	Yes	Crush (Remove rad tube?)
Neutron Generator, Explosive	Yes	Yes	Yes	Fire (mixed waste) or timer driver to explosive disposal/tube to rad waste
Reservoir	Yes	Yes	Yes	Bury (Remove rad material if appropriate)
Thermal Battery	Yes	No	Yes	Fire
Timers	No	No	No/Yes	None (Fire/Remove explosives if appropriate)
Use Control, PAL, CD Hardware	Yes	Yes	Yes	Expend, crush, shred, bury as appropriate

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Survey of Weapon Development and Technology (WR708) (U)

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Classified by: S. J. Barnes Dept. 3522
Title : Manager Date: June 6, 1995

CRITICAL NUCLEAR WEAPON DESIGN INFORMATION
-- DOD DIRECTIVE 5210.2 APPLIES --

NUCLEAR WEAPON DATA

SIGMA 1 &

Corporate Training & Development 3522

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

Day	Time	Session	Title	Instructor
Monday	8:30 - 12:00	1	Course Overview - Introduction	Hogan/Layne
		2	Physics - Explosion Theory	Hogan/Layne
	1:00 - 4:00	2	Physics - Explosion Theory (cont)	Hogan/Layne
		3	Nuclear Effects	Hogan/Layne
Tuesday	8:00 - 12:00	4	High Explosives - Detonators	Hogan/Layne
		5	Fission	Hogan/Layne
	1:00 - 4:00	5	Fisson (cont)	Hogan/Layne
		6	Thermonuclear	Hogan/Layne
Wednesday	8:00 - 12:00	6	Thermonuclear (cont)	Hogan/Layne
		7	Safety	Hogan/Layne
	1:00 - 3:00	7	Safety (cont)	Hogan/Layne
		8	Use Control - Access Control	Hogan/Layne
	3:00 - 4:00	9	Weapons Systems	Rogulich
Thursday	8:00 - 12:00	10	Dismantlement	Longmire
		11	Arming, Firing, and Initiation	Longmire
		12	Nuclear Testing	Hogan/Layne
	1:00 - 4:00	13	Transfer Systems	Robinson
		14	Fuzing	Hartwig
		15	Arms Control	Hogan/Layne
Friday	8:00 - 9:30	15	Arms Control (cont)	Hogan/Layne
	9:45 - 10:45	16	Non-Proliferation/Counter Proliferation	Taylor
	11:00 - 12:30	17	Stockpile Matters	Hogan/Layne
	1:30 - 4:30	18	Nuclear Weapons Musuem Tour	Hogan/Layne

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National Security Strategy: Deterrence

Decade	Implementation
1950	Massive Retaliation
1960	Flexible Response
1970	Flexible Response
1980	Flexible Response
1990	Last Resort

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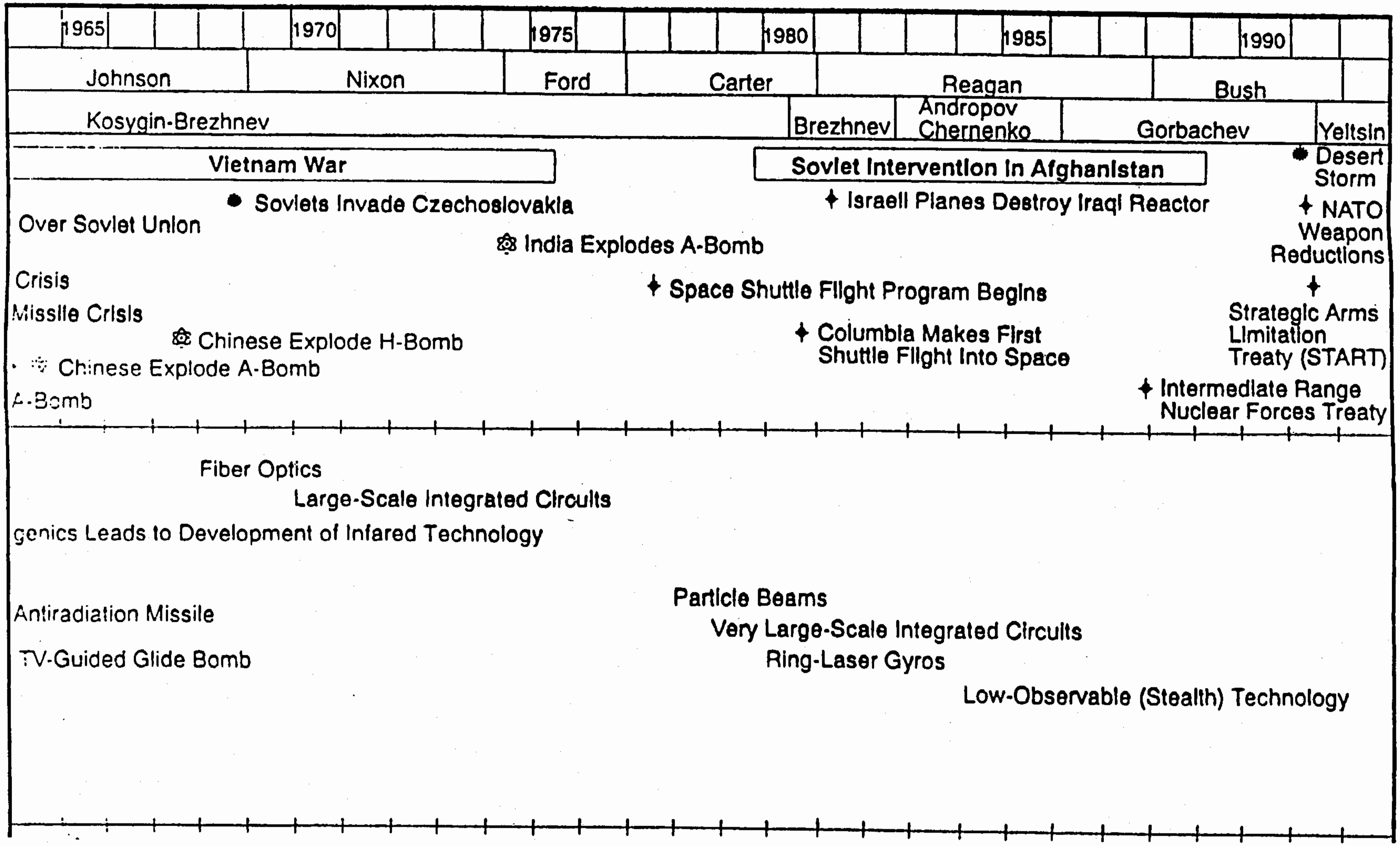
SIGNIFICANT HISTORICAL EVENTS RELATIVE TO NUCLEAR WEAPONS



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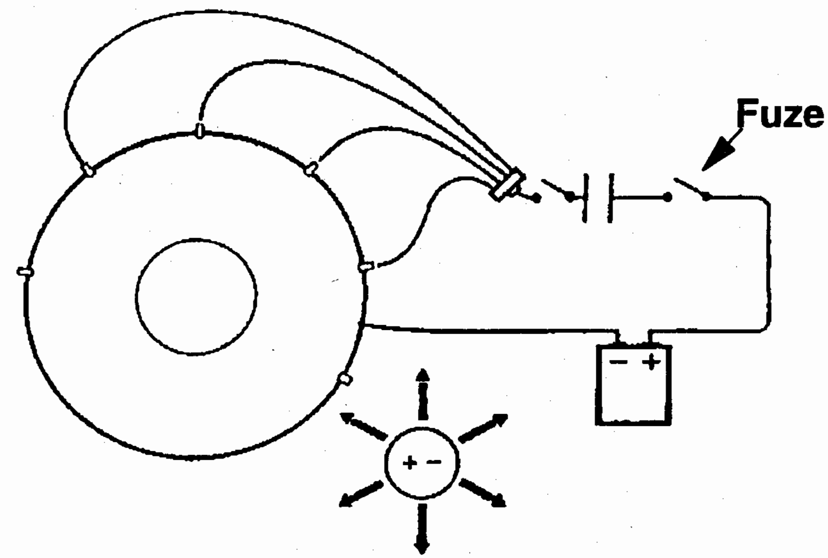
Strategy, Arms Control, and Weapon Systems Technology Drive Stockpile Requirements

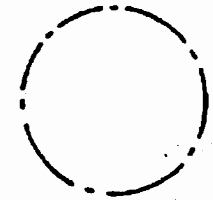
Strategy	Threat	Tech.	Size/Wt.	Yield	Arms Control	Number
1950 Massive retaliation	Global	A/C & missiles inaccurate	Large	Very high	Very limited talks	Growing
1960 Flexible response	Global Theater	A/C & missiles improve	Decrease	Decrease	Limited talks	Growing
1970 Flexible response	Global Theater	A/C & missiles improve accuracy	Decrease even more	Tactical needed lower yields	SALT ABM limitations	Decline
1980 Flexible response	Global Theater	A/C & missiles very accurate	Large decrease	Continued decrease	Mutual elimination & reduce	Decline more
1990 Last resort	Theater Global	A/C & missiles very accurate	Remain small	Remain same	Large cuts mutual elimination/ unilateral	Large reduction

Basic Elements of a Nuclear Weapon

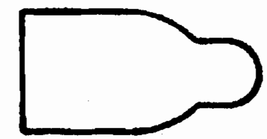


TERMINOLOGY

NUCLEAR PACKAGE
PHYSICS PACKAGE ⇨ PRIMARY/SECONDARY (Includes High Explosive)

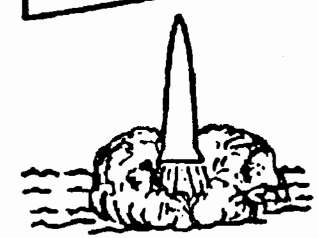


NUCLEAR WARHEAD ⇨ NUCLEAR PACKAGE & WEAPON ELECTRICAL SYSTEM & PLUMBING



NUCLEAR WEAPON ⇨ NUCLEAR WARHEAD & ARMING & FUZING & AERODYNAMIC CASE, ALSO REENTRY VEHICLE

NUCLEAR WEAPON SYSTEM ⇨ NUCLEAR WEAPON & DOD DELIVERY SYSTEM



–THE TERM <u>NUCLEAR DEVICE</u> USUALLY IMPLIES A TEST WARHEAD BUT IS SOMETIMES USED IN A PLACE OF EITHER NUCLEAR PACKAGE OR WARHEAD

–THE ARMY USED THE TERM NUCLEAR WARHEAD SECTION TO INCLUDE WARHEAD + AK + BALLISTIC BASE

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WEAPON PROGRAM OBLIGATIONS

STOCKPILE MANAGEMENT:

MAINTENANCE OF THE NATIONAL STOCKPILE OF NUCLEAR WEAPONS IN A SAFE, SECURE, RELIABLE, READY CONDITION

WEAPONIZATION:

DEVELOP AND PRODUCE NUCLEAR WEAPONS FOR STOCKPILE AS JOINTLY AGREED TO BY DOD & DOE AND AS AUTHORIZED BY THE PRESIDENT

WEAPON TECHNOLOGY:

PURSUE TECHNOLOGY IN THE SCIENCE & ENGINEERING OF NUCLEAR WEAPONS SO THAT OUR UNDERSTANDING & ABILITY TO DEVELOP IS SECOND TO NONE

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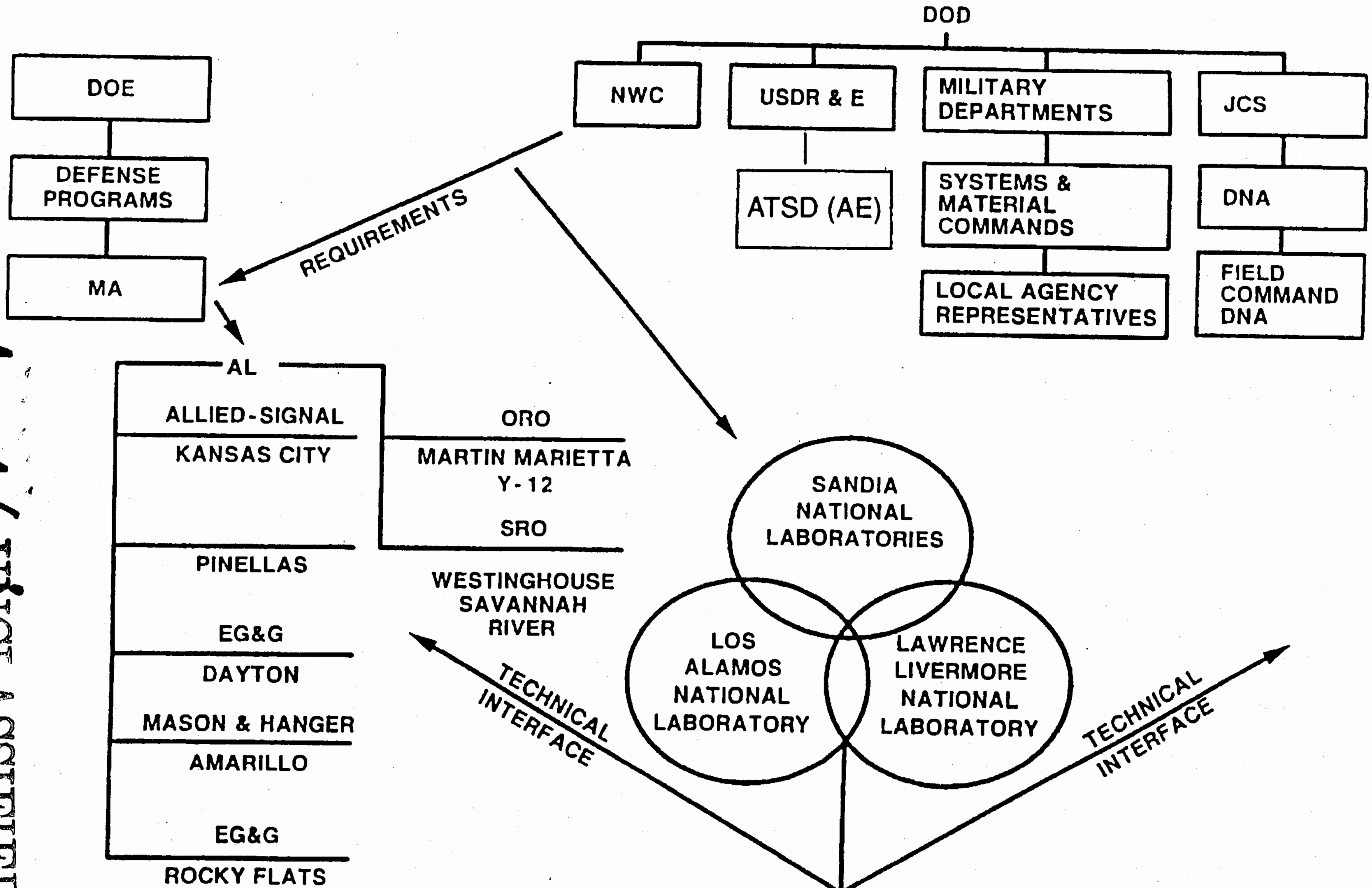
SANDIA-DOE/DOD INTERFACES
WEAPON PROGRAM



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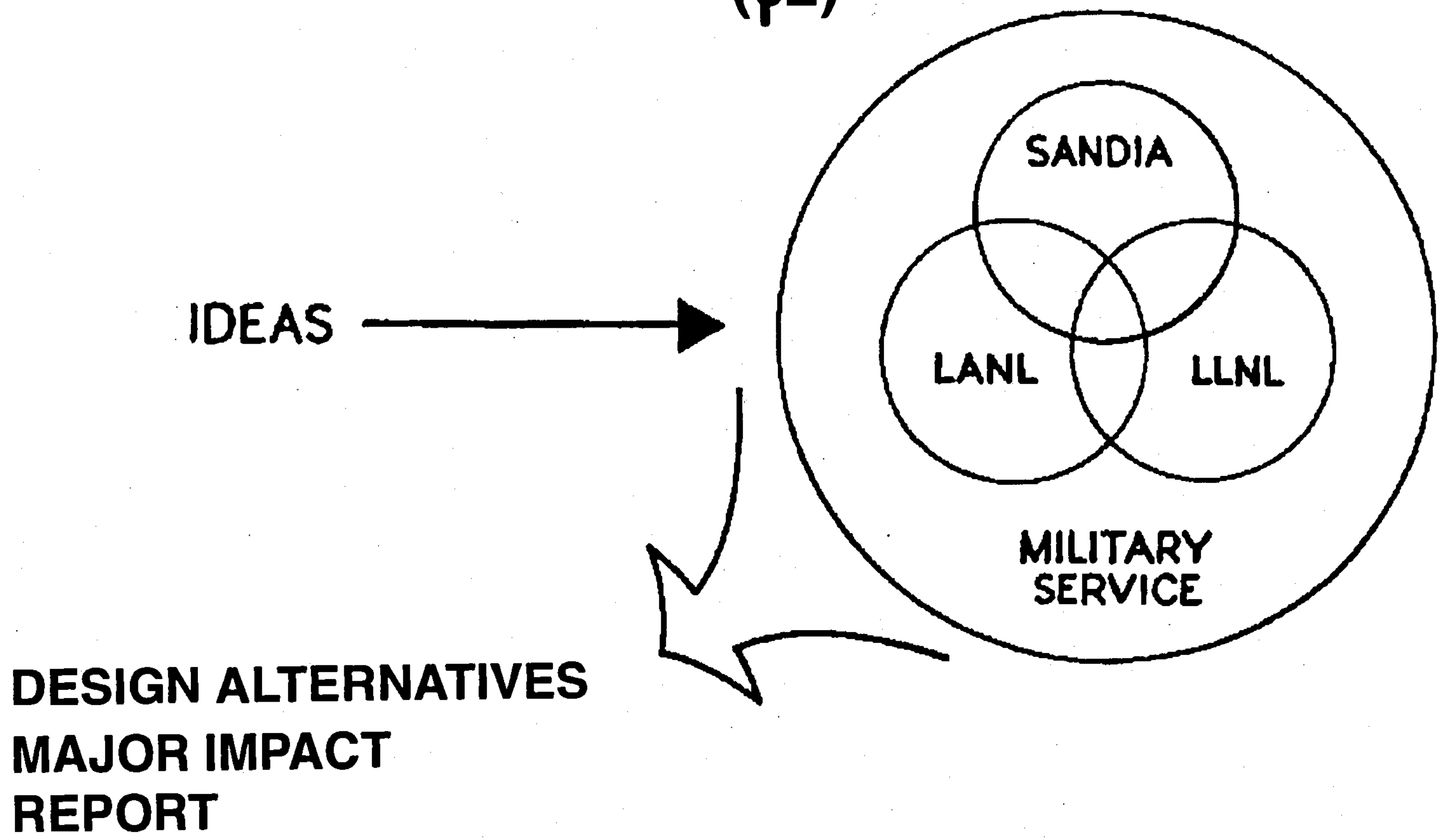
Historical Pressure on Nuclear Designs

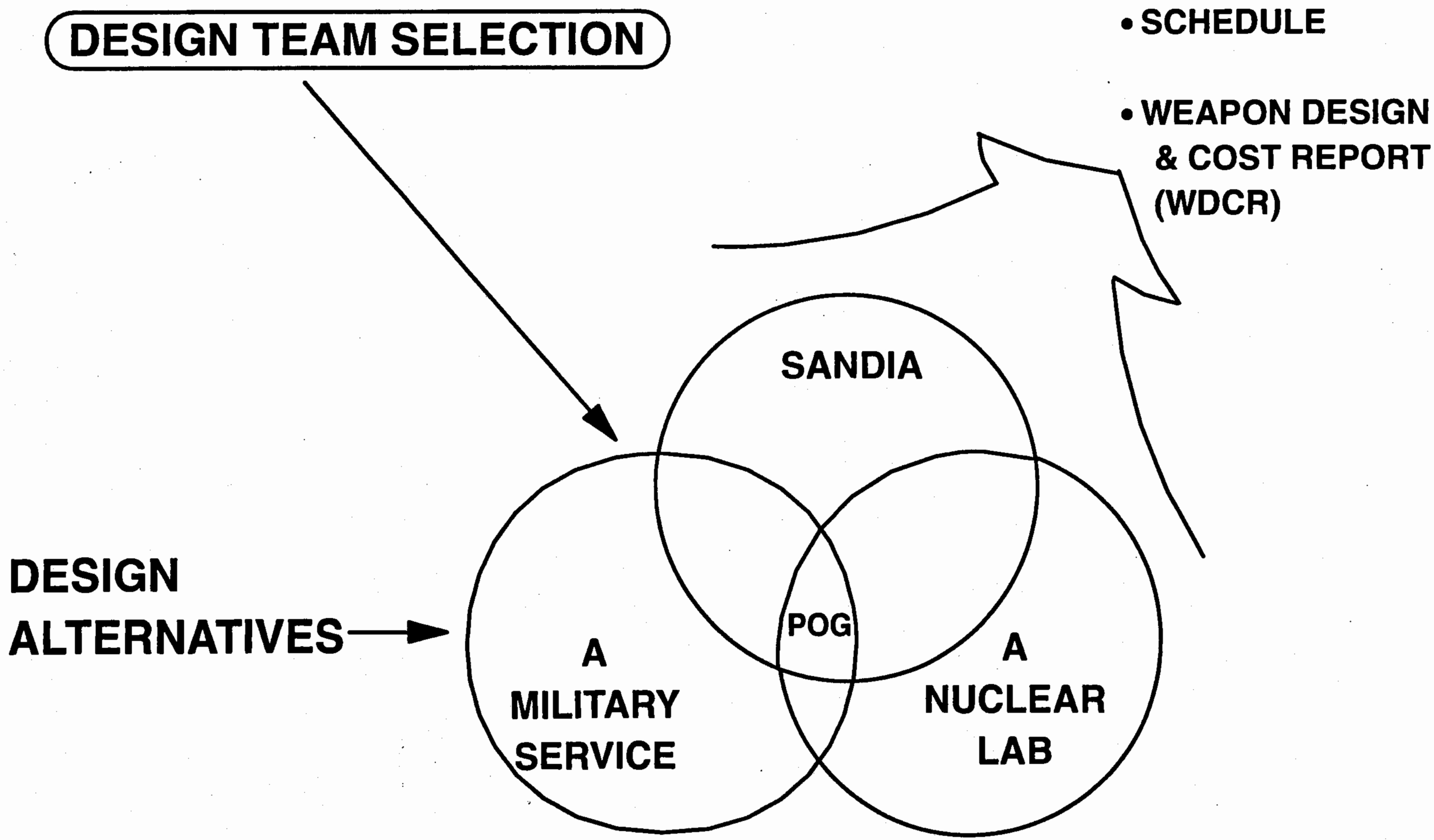
	PEACETIME EMPHASIS	WARTIME EMPHASIS
IMPROVE	SAFETY SECURITY CONTROL	SURVIVABILITY DELIVERABILITY EFFECTIVENESS FLEXIBILITY BATTLE MANAGEMENT
REDUCE	MAINTENANCE MOVEMENT TRAINING	REACTION TIME OPERATIONAL CONSTRAINTS COLLATERAL DAMAGE

PHASE 2 FEASIBILITY

(ϕ2)



Phase 2A VALIDATION (Φ2A)



Phase 2A - Design Definition and Cost Studies

A DOE design team will normally be selected and a Project Officer Group will be formed. The POG will conduct trade-off studies to identify baseline design(s) which best balances resources and requirements. Review and revise draft MCs and STs. Establish tentative development and production schedule and division of responsibilities. A Weapon Design and Cost Report will be prepared.

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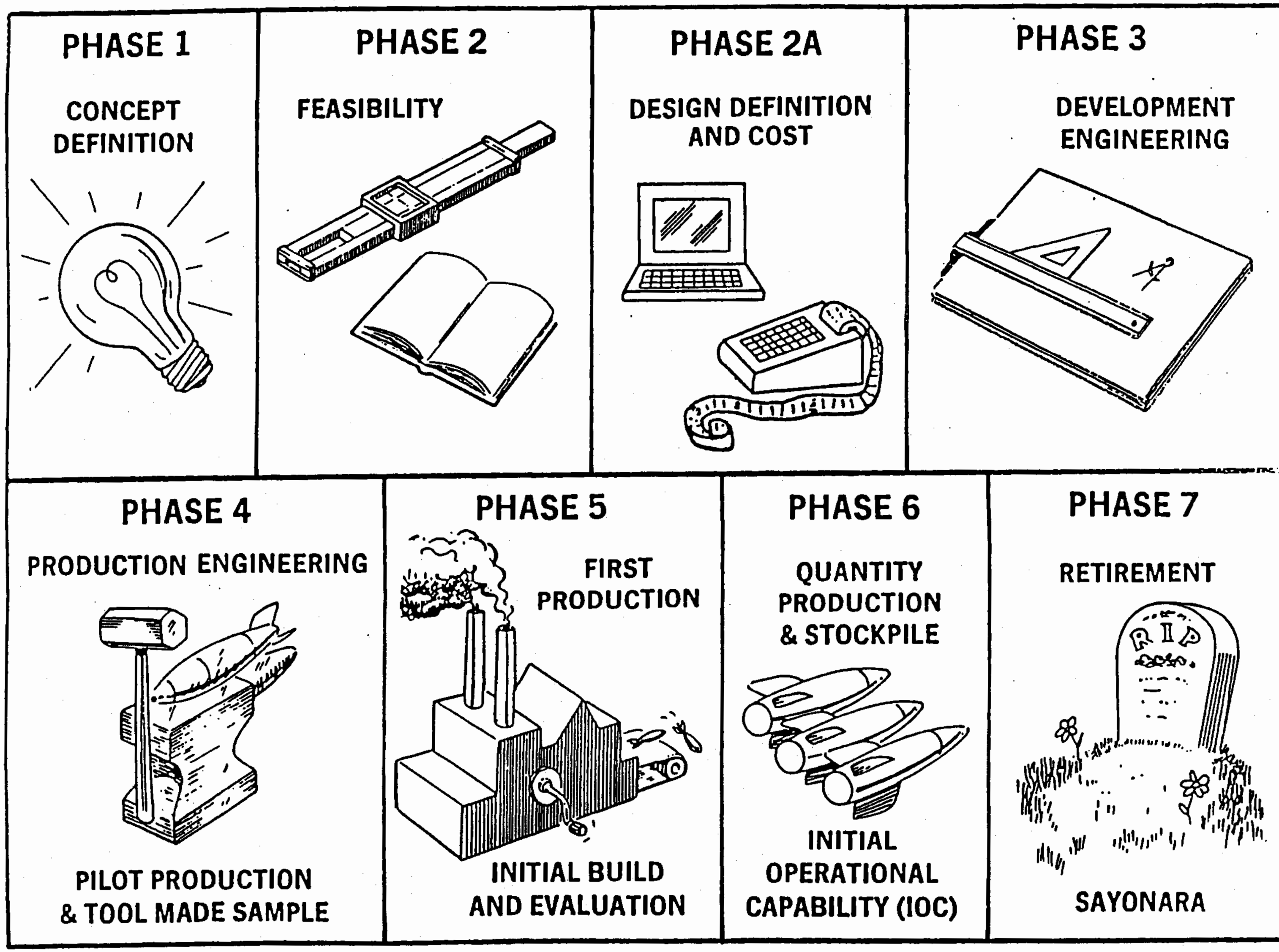
WEAPON DEVELOPMENT



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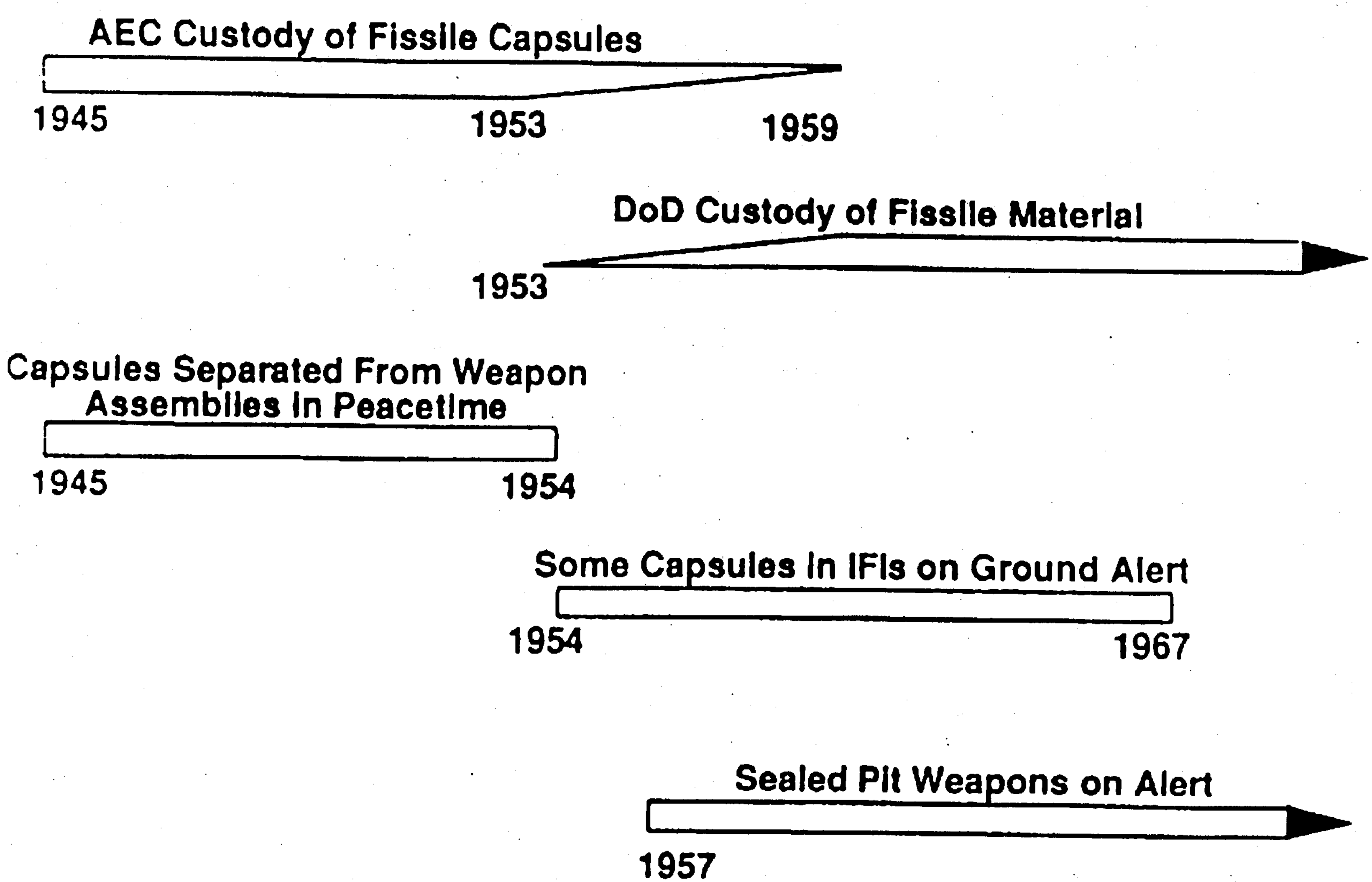
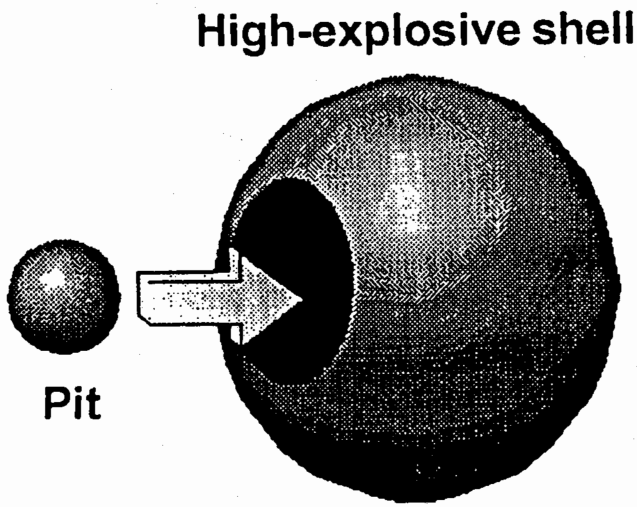
U. S. NUCLEAR DEPLOYMENTS CHANGED



Manually Inserted Capsules

1948 - 1951



- Safety Theme: Separation of fissile material and HE
- Analysis: Accident must assemble weapon

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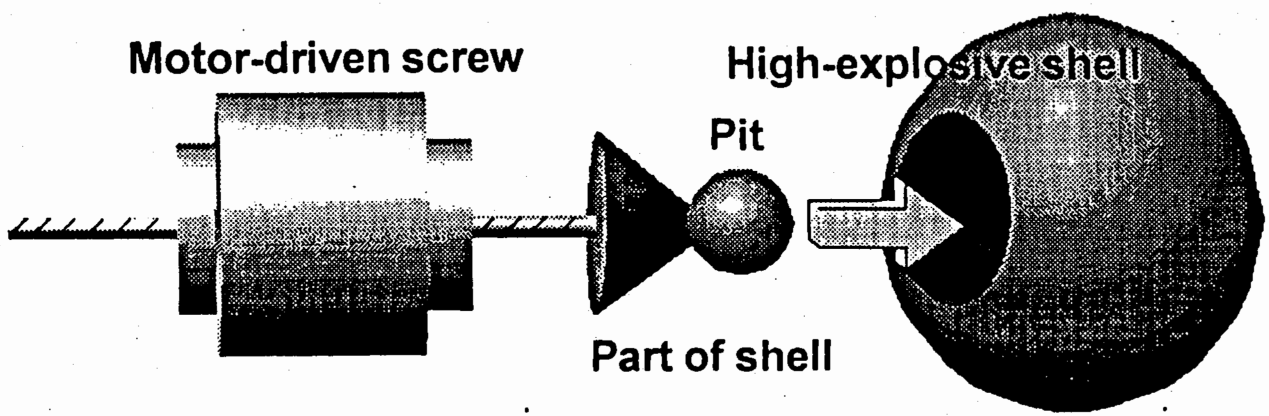
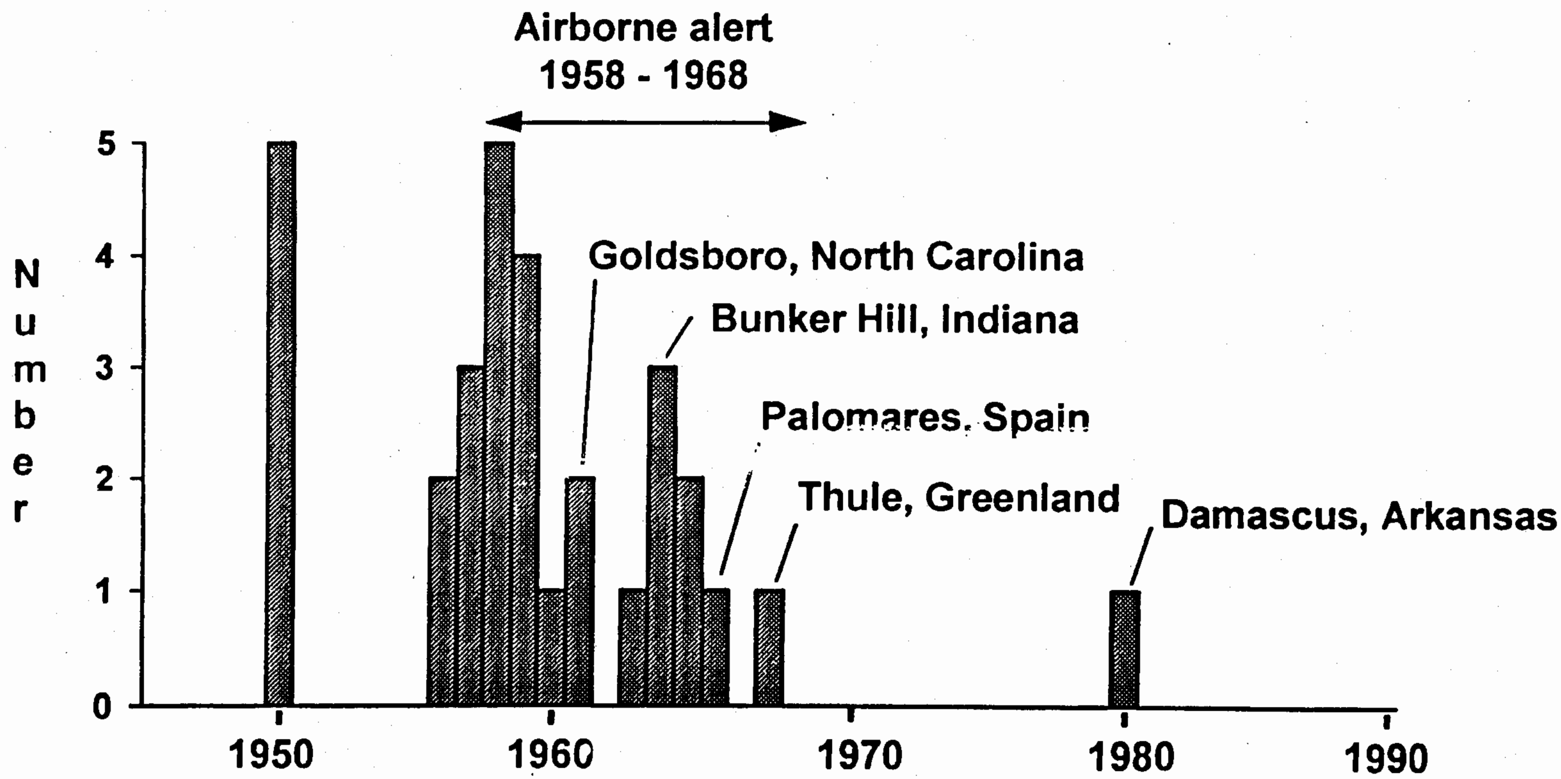
Mechanically Inserted Capsules

1952 - 1967



- Safety Theme: Separation of fissile material and HE and electrical isolation
- Analysis: Accident could assemble weapon by operating motor or by mechanical damage

US Nuclear Weapon Accidents



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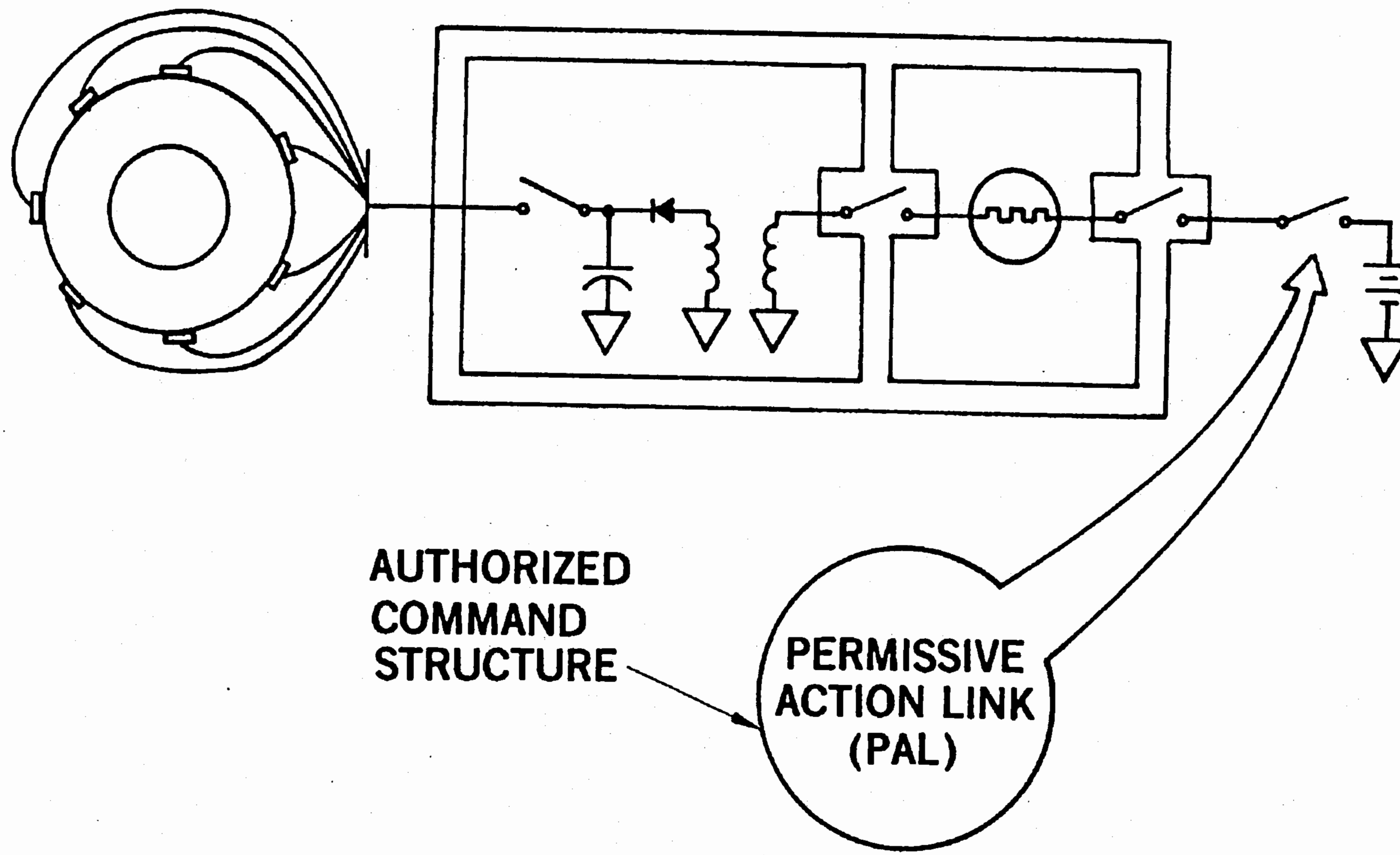
CONTROL - USE DENIAL



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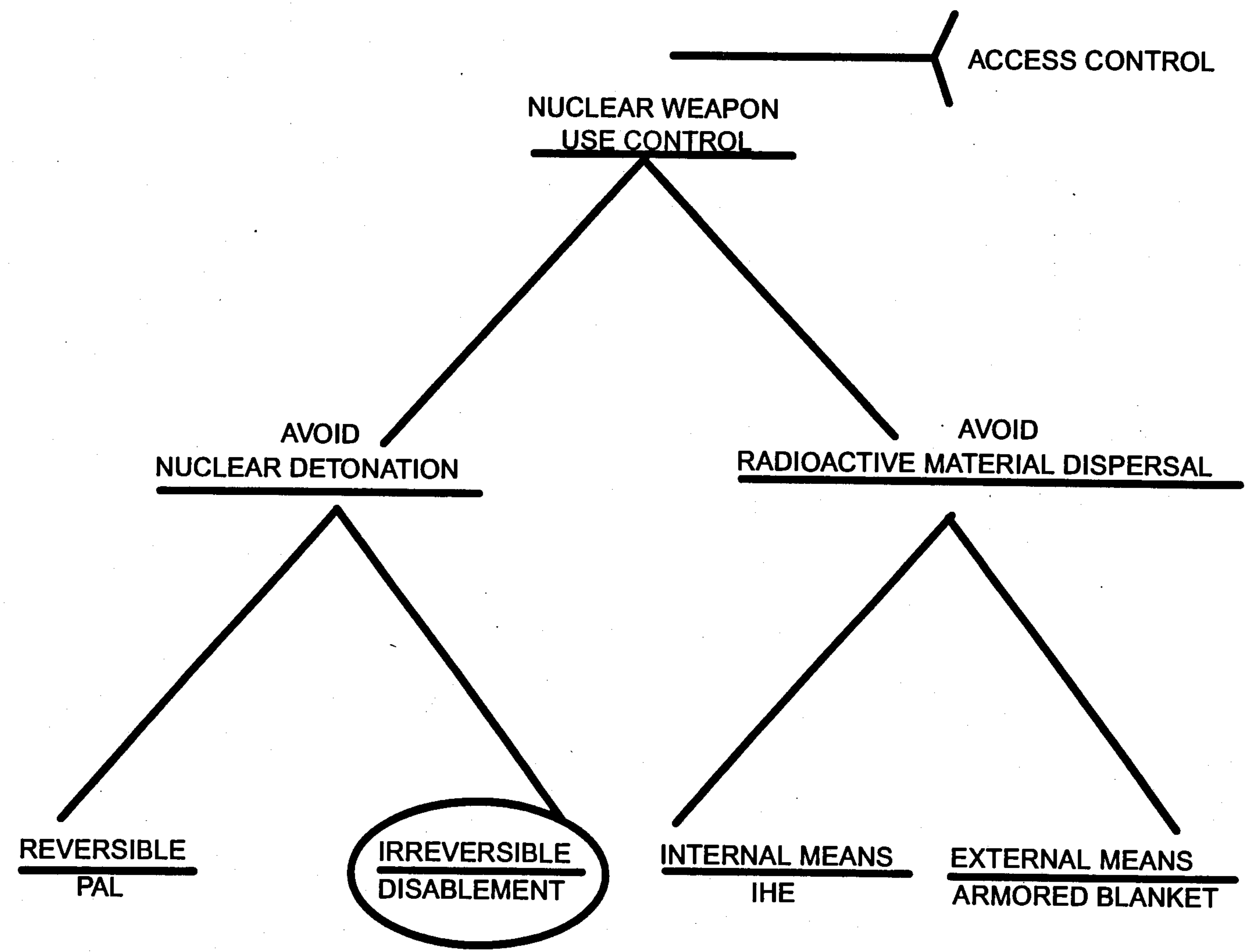

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DISABLEMENT

- When initiated, disables certain key nuclear detonation-essential components.

- Non-violent outside the weapon case.

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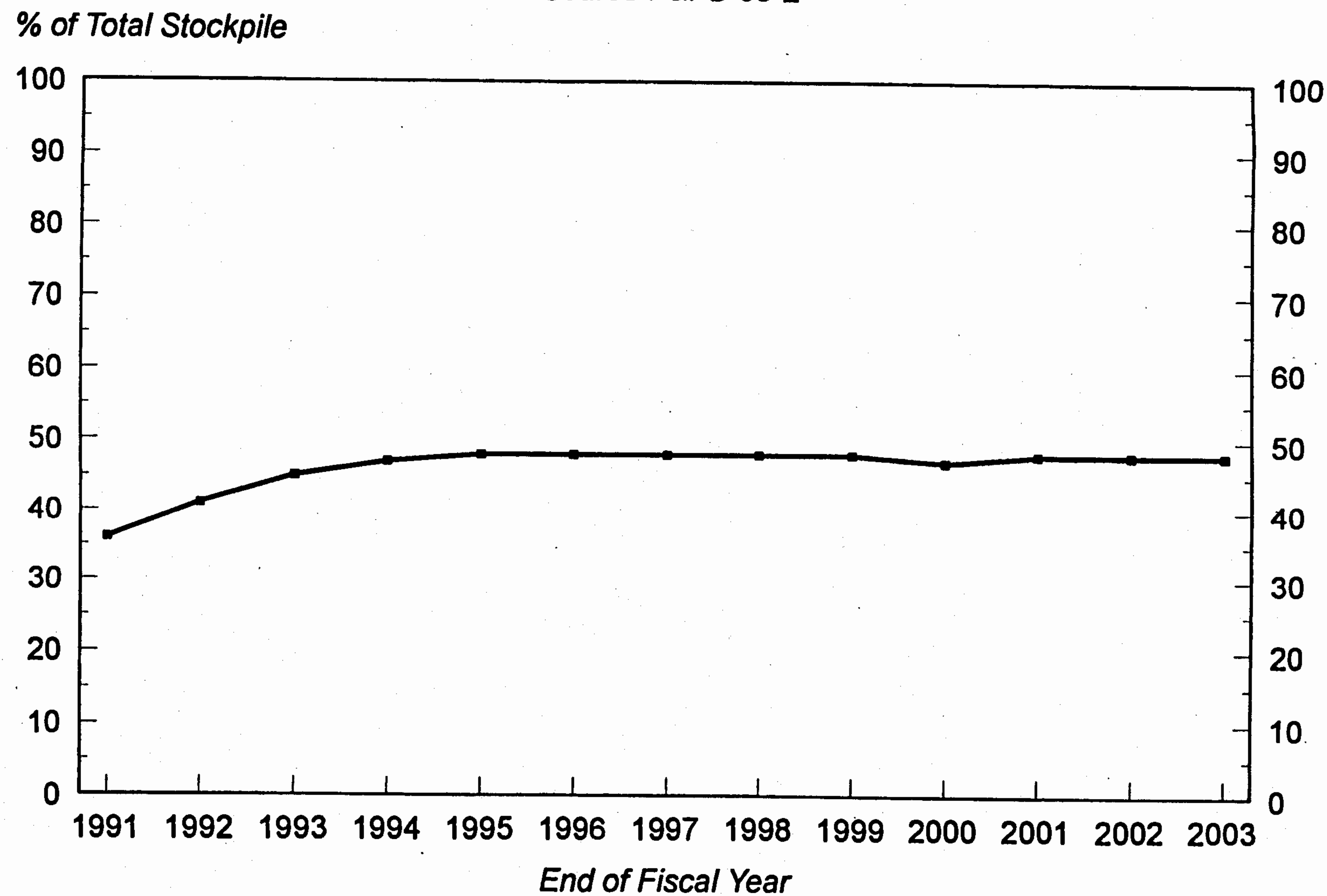
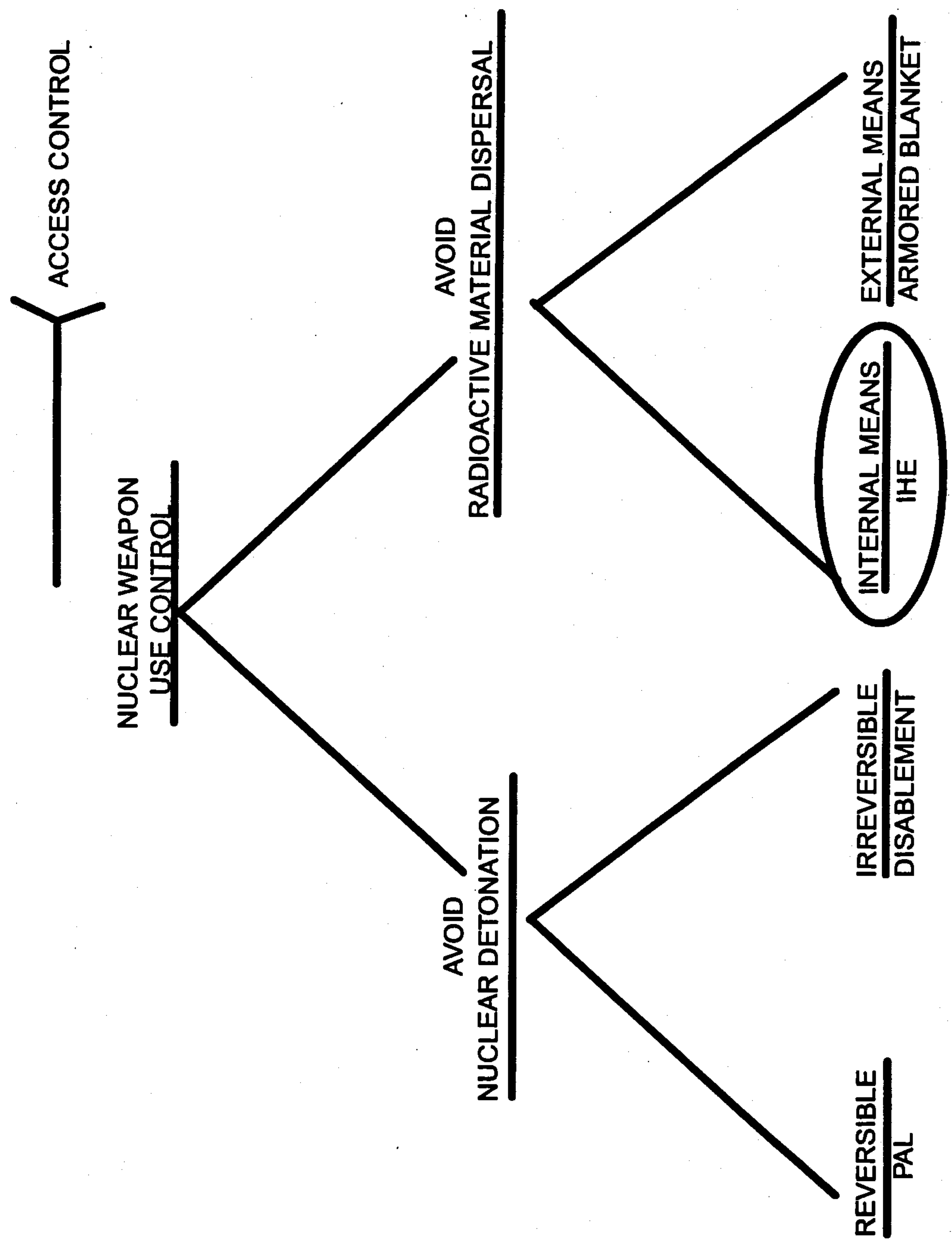
COMMAND DISABLEMENT

Source P&PD 93-2




NUCLEAR WEAPON
USE CONTROL
ACCESS CONTROL
AVOID
RADIOACTIVE MATERIAL DISPERSAL
AVOID
NUCLEAR DETONATION
EXTERNAL MEANS
ARMORED BLANKET
INTERNAL MEANS
IHE
IRREVERSIBLE
DISABLEMENT
REVERSIBLE
PAL

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An Overview of the Evolution of Aircraft Monitor and Control (AMAC) Systems

- System 1 offered many improved features in safety and compatibility.

- The requirements for a Unique Signal Generator (USG) first appeared in July 1975 to enhance weapon safety in abnormal environments.

- The requirements for CAT D PAL first appeared in August 1975.

- The requirements for Command Disable (CD) first appeared in October 1981 to provide the ability to render a weapon useless from the cockpit.

- All aircraft nuclear weapon interfaces built to date have been analog.

- A system 2 AMAC specification exists that defines a digital interface for possible use in future nuclear weapons.

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An Overview of the Evolution of Aircraft Monitor and Control (AMAC) Systems

- The result of this effort resulted in the T249 AMAC for bomber and fighter aircraft usage.

- New bombs designed during the mid to late '50s were made compatible with the T249 rather than building a unique AMAC for a specific bomb.

- AMAC design specifications, defined jointly by the DOE and DoD, first appeared in December 1961.

- The requirements for Category (CAT) B Permissive Action Link (PAL) first appeared in June 1963 to enhance weapon security.

- Today's nuclear-capable aircraft, with few exceptions, have what is known as a System 1 AMAC interface.

- The System 1 specification first appeared in September 1963.

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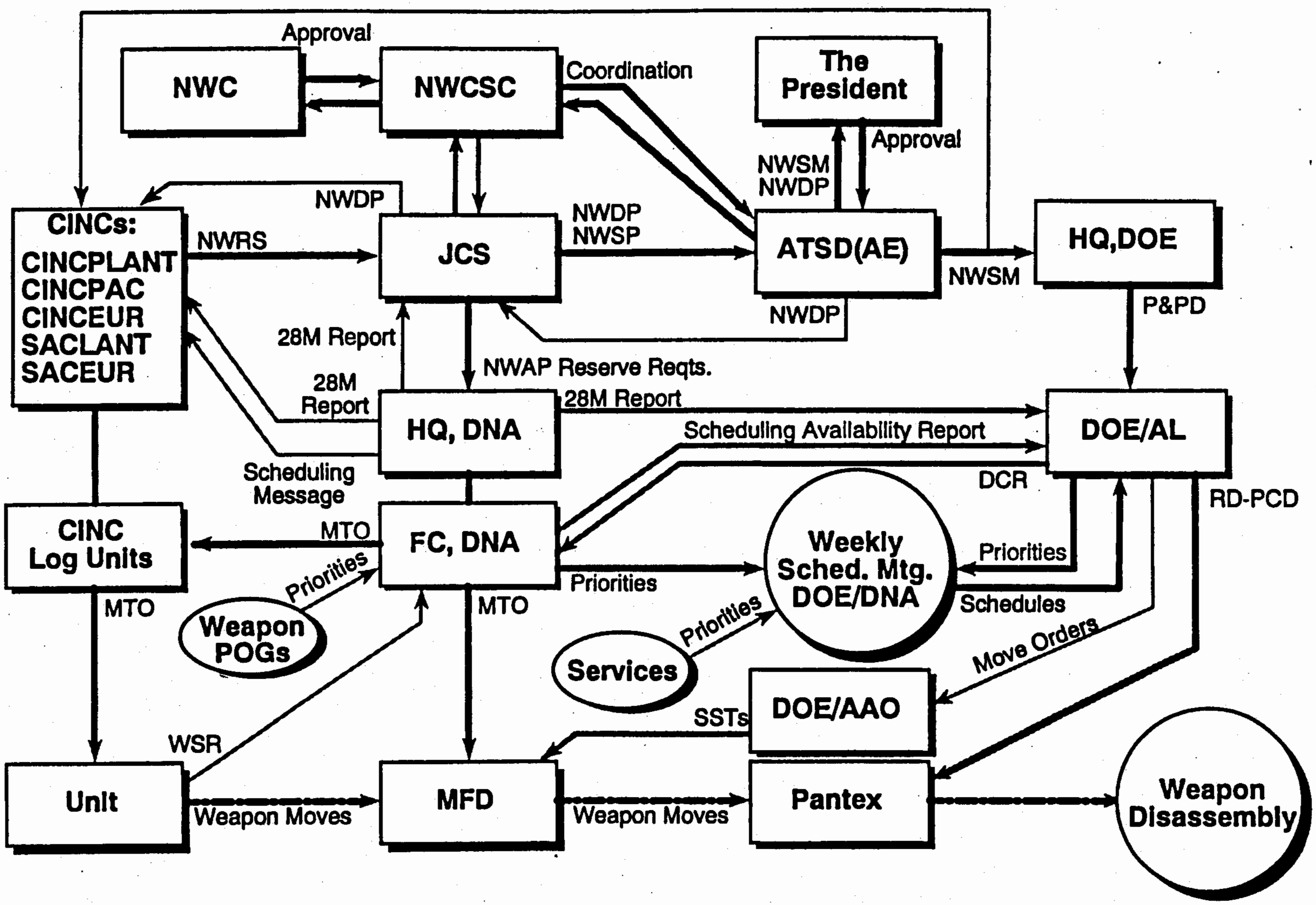
DISMANTLEMENT PRIORITIZATION PROCESS



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NEW LIST FOR FOIA AS OF JAN. 5, 2001

1. A DOCUMENT OF LOW-YIELD NUCLEAR EXPLOSION CALCULATIONS: THE VELA SIGNAL (U) BY E.M. JONES, R.W. WHITAKER, H. G. HORAK AND J. W. KODIS, LA- 9062, SAC200122580000, ISSUED ON MAY 1982 9/22/79
2. A DOCUMENT OF SYSTEMS RESEARCH REPORT ON A METHOD FOR AUTOMATED RECOGNITION OF SATELLITE RADIOMETRIC WAVEFORMS (U) BY CHARLES V. JAKOWATZ, JR., PAUL A. THOMPSON, SANDIA NATIONAL LABORATORIES, RS 0310/85/268, SAC200122590000, ISSUED ON NOVEMBER 1, 1985
3. A DOCUMENT OF J-14 FILE COPY, ISSUED MAY 5,1998, SAA200118530000, 98SA20A000254
4. A DOCUMENT OF ANALYSIS SUMMARY, P-14A-173, SAA2001186????, ISSUED 4/28/98
5. A CLASSIFIED RECORD CONTROL NO. 4-31446, DATED 3/16/65, TYPE "B" RADIATION EXPOSURE BY JAMES V. GLENN COMMITTEE CHAIRMAN AND H. JACK BLACKWELL, AREA MANAGER, SAC200144210000, DATED ON APRIL 20, 1965
6. MONTHLY FIRE REPORT FOR JANUARY, 1999, SAC200142920000, 256196
7. MONTHLY FIRE REPORT FOR DECEMBER 1999, 256197
8. MONTHLY FIRE REPORT FOR NOVEMBER 1998
9. MONTHLY FIRE REPORT FOR OCTOBER 1997
10. MONTHLY FIRE REPORT FOR FEBRUARY 1996
11. MONTHLY FIRE REPORT FOR JANUARY 1996
12. MONTHLY FIRE REPORT FOR DECEMBER 1995
13. MONTHLY FIRE REPORT FOR NOVEMBER 1995, 256405
14. October 31 Estimates from Mr. Oppenheimer to Gen. Groves regarding Implosion Method, SAC200141730000, 84-019 32-4, November 18, 1943
15. DOCUMENT #1, JOINT DOD/DOE TRIDENT MK4/MK5 REENTRY BODY ALTERNATE WARHEAD PHASE 2 FEASIBILITY STUDY REPORT (U), BY DAVID A. PONTON, JAMES V. TYLER, DONALD D. TIPTON, DOUGLAS R. HENSON, KARL B. RUEB AND BARRY W. HARMAH, SAB20017421B001, 99SA20B000347, DATED JANUARY 1994
16. DOCUMENT #2, HPRF PHASE 2 STUDY GENERAL MEETING 94-3 (#10) MINUTES, BY KEITH M. BAIRD, HPRF STUDY DIRECTOR, SAB20017422B001, DATED OCTOBER 28, 1994
17. DOCUMENT #3, HIGH POWER RADIO FREQUENCY, PHASE 2 STUDY GENERAL MEETING 94-2 (#9), BY KEITH M. BAIRD, NWIC-MM-94-2, SAB20017423B001, DATED JULY 15, 1994
18. DOCUMENT #4, HIGH POWER RADIO FREQUENCY, PHASE 2 STUDY GENERAL MEETING 94-1 (#8), BY KEITH M. BAIRD,NWIC-MM-94-1, SAB20017424B001, DATED MARCH 10, 1994
19. DOCUMENT #5, HIGH POWER RADIO FREQUENCY, PHASE 2 STUDY MEETING #4 MINUTES (U), BY CAPTAIN WILLIAM A. LAMB, OAS-MM-93-1, SAB20017425B001, APRIL 19, 1993
20. DOCUMENT #6, JOINT DOD/DOE PHASE 2 FEASIBILITY STUDY OF A HIGH POWER RADIO FREQUENCY WEAPON, FINAL REPORT (U), BY JOHN R. CURRY, DATED FEBRUARY 20, 1996
21. DOCUMENT #7, HIGH POWER RADIO FREQUENCY, PHASE 2 STUDY MEETING #3 MINUTES (U), BY CAPTAIN WILLIAM A. LAMB, OAS-MM-92-15, SAB20017427B001, DECEMBER 11 1992
22. DOCUMENT #8, HIGH POWER RADIO FREQUENCY PHASE 2 STUDY GENERAL MEETING 94-4 (#11) MINUTES, BY KEITH M. BAIRD, SAB20017428B001, DATED JANUARY 4, 1995
23. DOCUMENT #9, HIGH POWER RADIO FREQUENCY PHASE 2 STUDY GENERAL MEETING 95-1 (#12), BY KEITH M. BAIRD, SAB20017429B001, DATED JANUARY 31 TO FEBRUARY 1, 1995
24. DOCUMENT #10, HIGH POWER RADIO FREQUENCY PHASE 2 STUDY KICKOFF MEETING MINUTES (U), BY CAPTAIN WILLIAM A. LAMB, OAS-MM-92-10,SAB20017430B001, DATED OCTOBER 8, 1992